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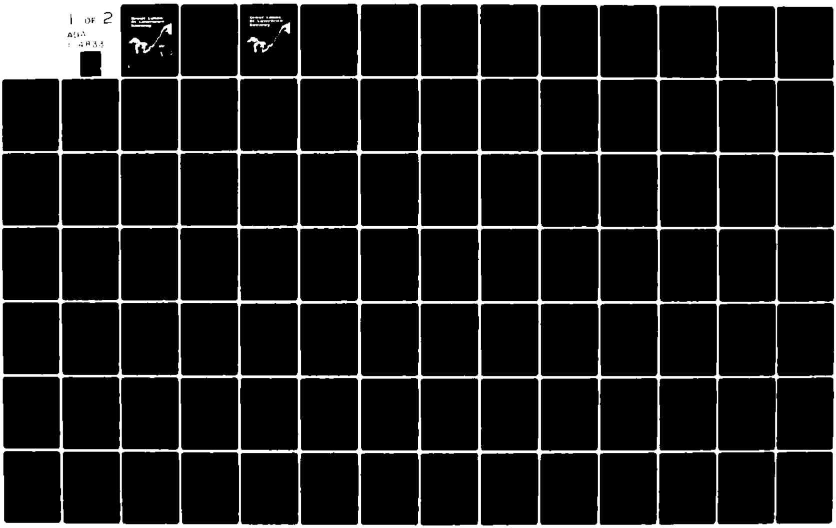

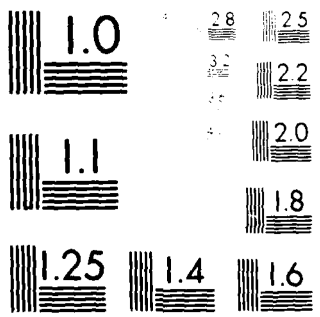


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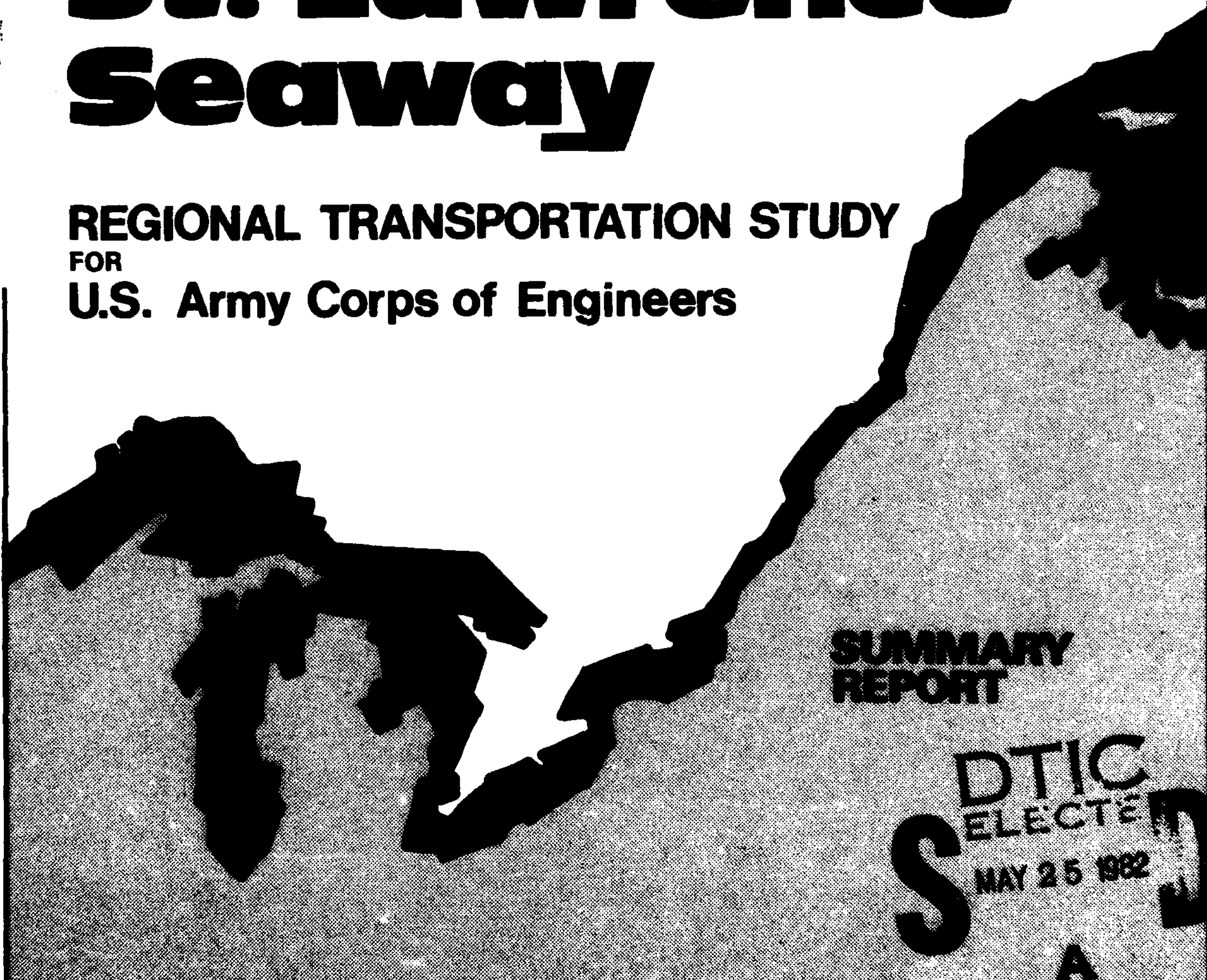
# Great Lakes/ St. Lawrence Seaway

## REGIONAL TRANSPORTATION STUDY
FOR
## U.S. Army Corps of Engineers



**SUMMARY REPORT**



BOOZ·ALLEN & HAMILTON INC.
IN ASSOCIATION WITH ARCTEC, Inc.
APRIL 1982

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| containerized cargo | non-structural modifications | |
| traffic forecasts | structural improvements | |
| freight rates | regional impacts | |

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report documents the research undertaken during both phases of a two phase investigation of physical modifications to the Great Lakes-St. Lawrence River. This report identifies the relative merits of improvement alternatives and makes recommendations for areas of further detailed study. Results of Phase II are documented in a separate report.

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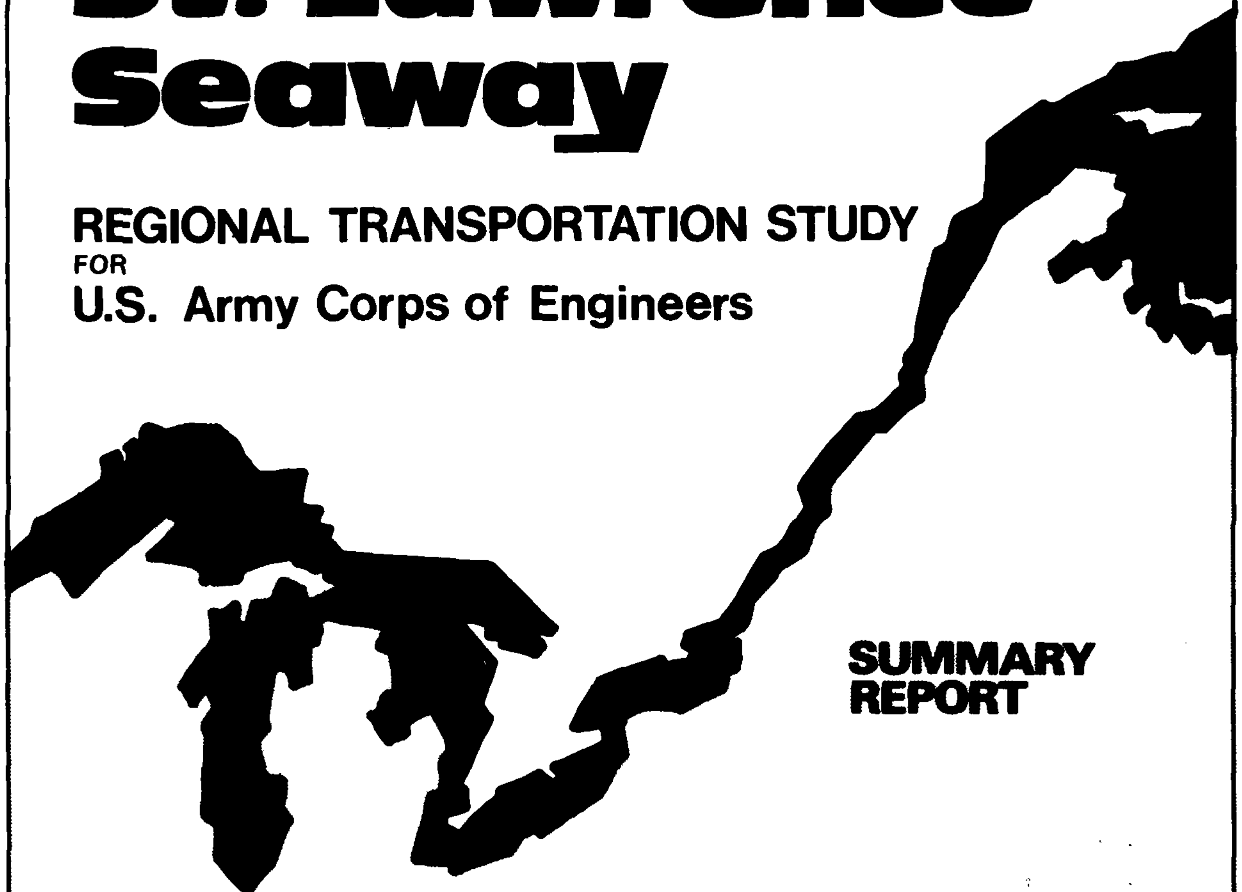
# Great Lakes/ St. Lawrence Seaway



## REGIONAL TRANSPORTATION STUDY
FOR
## U.S. Army Corps of Engineers

**SUMMARY REPORT**



BOOZ·ALLEN & HAMILTON INC.

**IN ASSOCIATION WITH ARCTEC, Inc.**
**APRIL 1982**

## ACKNOWLEDGMENTS

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Mr. Leo J. Donovan, Vice President of Booz, Allen, was officer-in-charge of the assignment. Timothy J. Consroe was project manager, and was assisted by John C. Martin, M. Kathleen Broadwater, and W. Scott MacKinnon. Mr. Thomas V. Kotras and Mr. Lawrence A. Schultz, Vice Presidents of Arctec, Inc., were responsible for that firm's contribution to the project.

T A B L E   O F   C O N T E N T S

Page Number

# I. INTRODUCTION

# I. INTRODUCTION

The U.S. Army Corps of Engineers is responsible for maintaining navigability in U.S. rivers, waterways, and harbors. The Corps currently maintains a navigation system of 25,000 miles of improved channels and 219 locks and dams connecting large regions of the country. Feasibility analyses and planning that precede lock and channel construction and maintenance are integral components of navigation system projects. The Great Lakes/St. Lawrence Seaway Regional Transportation Study is one element of this planning process.

The objective of the GL/SLS Regional Transportation Study is to develop an up-to-date, working analytical tool for economic analysis of GL/SLS transportation system improvements. The near-term uses of study information are feasibility studies of three Great Lakes navigation system improvements. These studies are the following:

- The St. Lawrence Additional Locks Study, which will determine the adequacy of the existing locks and channels in the U.S. section of the seaway in light of present and future needs
- The Great Lakes Connecting Channels and Harbor Study, which will determine the feasibility of providing navigation channel, harbor and lock improvements to permit transit of vessels up to the maximum size permitted by the possible replacement locks at Sault Ste. Marie
- The Great Lakes-St. Lawrence Seaway Navigation Season Extension Study, which considers the feasibility of means of extending the navigation season on the entire system.

The study is organized in two phases. Phase I has the following elements:

- Development of cargo flow forecasts for the Great Lakes system

- Development of data bases required for the evaluation of national economic development (NED) benefits and costs of navigation system improvements

- Evaluation of lock system performance and ability to process future cargo flows

- Evaluation of the performance and economic feasibility of improvements to increase the capacity of the system.

Phase II of the study assesses the regional economic, social, intermodal, and energy use impacts of alternative improvements.

This report summarizes the work steps undertaken to accomplish Phases I and II of this study and presents an initial evaluation of specific system improvement scenarios. This preliminary feasibility analysis identifies the relative merits of improvement alternatives and identifies the areas which should be analyzed in more detail before improvement programs are recommended.

This report is organized as follows. The next three chapters summarize the results of Phase I of the study. Chapter II provides an overview of the ten specific work elements contained in this study phase. Chapter III documents the methodology used for analysis of costs and benefits, and Chapter IV provides the initial evaluation of benefits and costs. Chapter V summarizes Phase II of the study and includes an assessment of the potential regional economic, social, intermodal and energy use impacts of alternative improvements.

Complete documentation of the Phase I work elements consists of ten reports produced under separate cover. Phase II is documented in a single report under separate cover.

# II. SUMMARY OF PHASE I WORK ELEMENTS

## II. SUMMARY OF PHASE I WORK ELEMENTS

Phase I of the study consisted of eleven work elements, ten of which are documented under separate cover. The final work element in Phase I was a preliminary assessment of the life-cycle benefits and costs of alternative capacity improvements to the system using discounted cash flow techniques. The next chapter in this report documents that analysis.

Six of the elements deal with the supply of transportation service in the Great Lakes and the cost of system improvement, and resulted in the following reports:

- Description of the Physical System. This report is a compilation of data which describes the physical and operational characteristics of the locks, connecting channels and harbors which make up the system.

- The Existing and Future Great Lakes Fleet. This report describes the current fleet and develops an estimate of the future fleet based on predictions of commodity demand, retirement rates and fleet building trends.

- Update of the Maximum Ship Size Study. Construction and maintenance costs of alternative system improvements are updated in this report.

- Evaluation of Lock Capacity Models. In this report twelve lock capacity models are evaluated and the Corps' Lock Capacity Model is selected as the preferred model for use in this study.

- Lock Performance and Alternatives for Increasing Capacity. This report describes locking procedures at each lock system, identifies operational problems, and identifies structural and non-structural techniques for increasing lock capacity.

- Feasibility Analysis of Capacity Expansion Measures. This report describes calibration of the lock capacity model and use of the model to evaluate the effectiveness of various capacity

expansion scenarios. Complete documentation of the capacity model used in the feasibility analysis is provided.

The other four elements of the study dealt with the demand for transportation service in the system and the benefits of system improvements. These reports were produced:

- The Competitive Position of the Great Lakes for Containerized Cargo. This report summarizes historical trends in general cargo shipping on the Great Lakes, and evaluates the potential for future general cargo shipping in terms of shipper requirements and carrier operating costs.

- Great Lakes Industry Studies. Separate reports were prepared for the grain and steel industries and for the industries which are major coal consumers in the Great Lakes area. These reports identify trends and the outlook for production and consumption of the major commodities shipped via the lakes, locate major plants, and analyze commodity distribution systems.

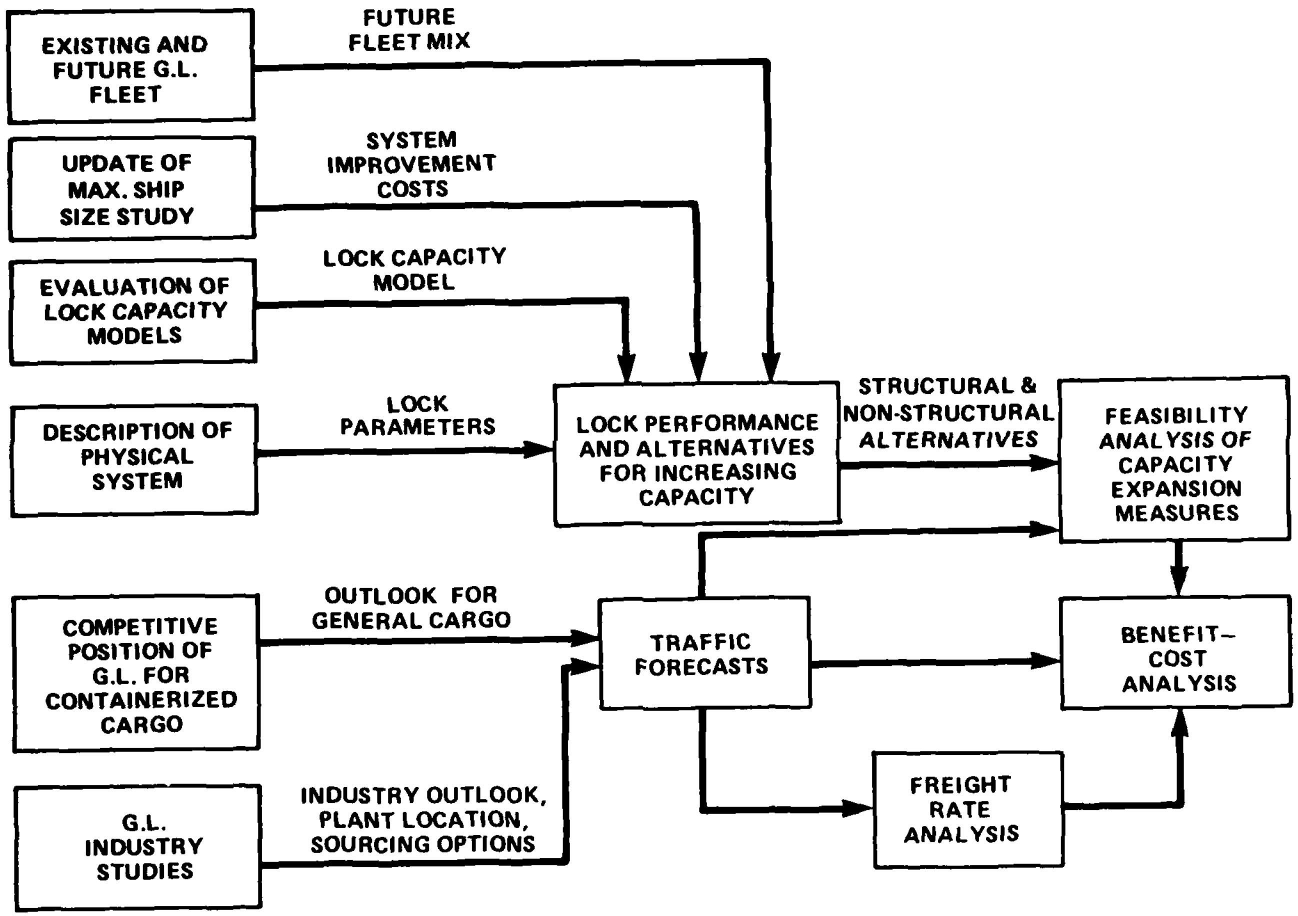
- Traffic Forecasts. Traffic forecasts were developed for a base year of 1978 and extended to the year 2050. The forecasts contain detail for fifteen commodities. The forecasts of U.S. trade (including domestic, Canadian and overseas) identify the U.S. shipping and/or receiving port. Canadian trade is identified by lock system and direction.

- Rate Analysis. A file of freight rate information was developed for the major commodity movements using the Great Lakes system. Rail, truck, barge, laker and ocean rates were collected in order to identify total transportation costs for current Great Lakes routes and for the least expensive alternative routes. These rates are the basis for estimation of rate savings benefits of system improvements.

Figure II-1 is a schematic illustration of the interrelationship of the Phase I study elements.

The following sections summarize the principal findings and conclusions of the ten work elements identified above.

FIGURE II-1
Phase I Study Elements



## 1. DESCRIPTION OF THE PHYSICAL SYSTEM

The Great Lakes/St. Lawrence Seaway System (GL/SLS) provides a shipping link between the deep water of the Atlantic Ocean and U.S. and Canadian ports located as much as 2,400 miles inland on the North American continent. Major sections of the system include 1,000 statute miles in the St. Lawrence River, the five Great Lakes, and 400 miles in connecting channels. In that distance there are sixteen sets of locks that lift ships from sea level to an elevation of 600 feet in Lake Superior. Figure II-2 illustrates the GL/SLS system. Figure II-3 is a schematic cross section of the locks of the system.

The physical system consists of harbors, locks and connecting channels. Table II-1 identifies the principal U.S. harbors in the system. Table II-2 summarizes channel dimensions and restrictions to navigation.

Connecting channels are maintained at the depth authorized by law; however, the actual depth of water in the channel varies because of daily and seasonal weather conditions plus silting caused by channel flow. Seasonally, the depth of water in the channels is affected by the water level in the lakes. The average elevation of the lake surfaces varies from year to year and over longer periods of time, typically a decade or more. These differences are basically due to the amount of precipitation and run-off that occur during the cycle. During any given year, the surface is typically lowest during the winter months and highest during the summer months.

Besides the long-term variations in channel depth, there are also short-term variations that can occur in a matter of hours. For example, low barometric pressure can cause channel depth to increase appreciably over a short period of time. Strong winds from a constant direction can either reduce or increase channel depth in a short time. The differences in depth caused by the wind are generally apparent at the ends of the lake. Short-term changes of as much as 8 feet have been recorded for an eight-hour period.

The three lock systems in the GL/SLS system, the St. Lawrence system, the Welland Canal and the Soo Locks, are described below.

The St. Lawrence River connects Lake Ontario to the Gulf of St. Lawrence. The St. Lawrence lock system extends approximately 190 miles from St. Lambert Lock at Montreal to Kingston, Ontario, on Lake Ontario.

FIGURE II-2
The Great Lakes/St. Lawrence Seaway System

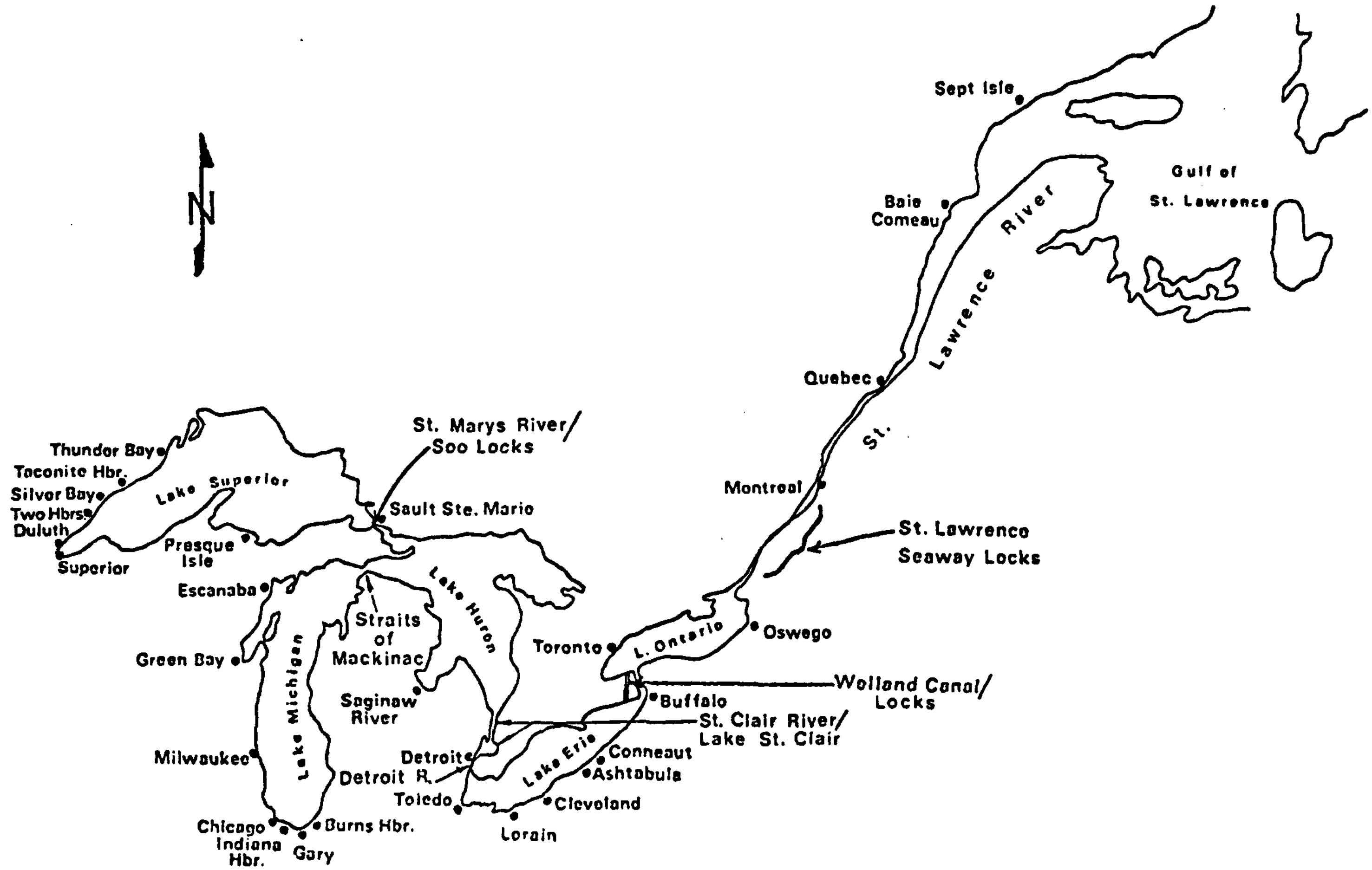


FIGURE II-3
Profile of Great Lakes/St. Lawrence Navigation System

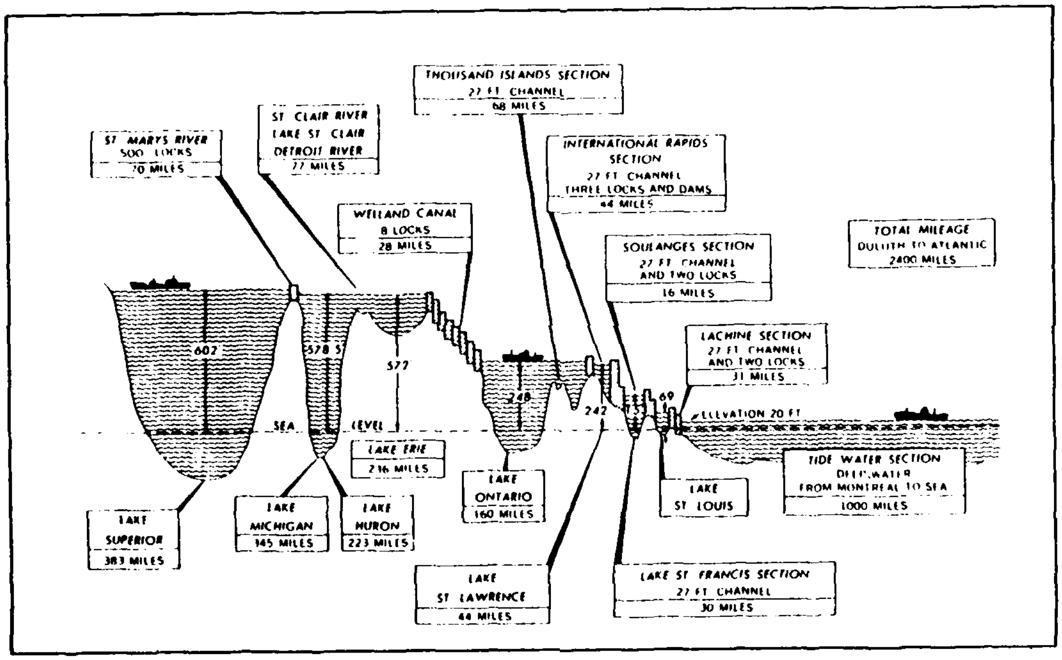


TABLE II-1
U.S. Harbors in the Great Lakes/
St. Lawrence Seaway System Included in the Study

LAKE SUPERIOR

Two Harbors, MN
Duluth-Superior, MN-WI
Presque Isle, MI
Marquette, MI
Taconite, MN
Silver Bay, MN
Ashland, WI

LAKE MICHIGAN

Green Bay, WI
Milwaukee, WI
Chicago, IL
Calumet Harbor, IN-IL
  Lake Calumet
Indiana Harbor, IN
Burns Waterway, IN
Muskegon, MI
Gary, IN
Escanaba, MI
Grand Haven, MI
Ludington, MI
Buffington, IN
Port Inland, MI
Port Washington, WI

LAKE ONTARIO

Oswego, NY
Rochester, NY
Ogdensbury, NY

LAKE HURON

Saginaw, MI
St. Clair River, MI, St. Clair
Port of Detroit, MI
  Detroit Harbor, Rouge River,
  Ecorse, Wyandotte, Riverview
Alpena, MI
Stoneport, MI
Drummond Island, MI
Port Dolomite, MI

LAKE ERIE

Toledo, OH
Sandusky, OH
Huron, OH
Lorain, OH
Cleveland, OH
Ashtabula, OH
Conneaut, OH
Erie, PA
Port of Buffalo, NY
  Niagara River, Buffalo River
Monroe, MI
Fairport, OH
Marblehead, OH

TABLE II-2
GL/SLS Connecting Channels

| Channel | Draft (ft) | Length (miles) | General Channel Width (ft)[1] | Fall (ft) | Restrictive Width[2] (ft) |
|---|---|---|---|---|---|
| St. Marys River | 27-30 | 63-75 | 300-1500 | 22 | 75,105[3] |
| Straits of Mackinac | 30 | 0.8 | 1250 | 0 | NA |
| St. Clair River | 27-30 | 46 | 700-1400 | - | 600[4] |
| Lake St. Clair | 27.5 | 17 | 700-800 | 8 | NA |
| Detroit River | 27.5-29.5 | 32 | 300-1260 | - | 100 |
| Welland Canal[5] | 26 | 27 | 192-350 | 326 | 76 |
| St. Lawrence River | 26 | 189 | 225-600 | 226 | 76[4,6] |

Notes:

1. Width of open channel, not including structures such as locks.

2. Lock widths show maximum ship size allowed.

3. Parallel locks, not including Canadian Lock which is generally not used.

4. Bridge restrictions.

5. A 4.5-mile section of the reach between Locks 7 and 8 is restricted to one-way navigation. A phased widening program will reduce the length of restricted channel to 3.0 miles for the 1982 season. The effect of the one-way restriction should be minimal after widening.

6. Lock restrictions.

The system was created by excavation of channels to a depth of 27 feet, permitting the transit of vessels drawing 26 feet, and the construction of seven single locks to bypass certain rapid sections of the river. These locks provide a total lift of 228 feet.

Of the seven locks, two are operated by the United States, the Snell and Eisenhower Locks located near Massena, New York. Five locks are operated by Canada: the St. Lambert and Cote Ste. Catherine Locks located near Montreal, the Upper and Lower Beauharnois Locks located in the Beauharnois Power Canal, and the Iroquois Lock located at Iroquois, Ontario. All seven locks are similar in size and all are capable of locking a ship that has a length of 730 feet, a beam of 76 feet, and a draft of 26 feet.

The major constraint to traffic is generally considered to be the Beauharnois Locks. These locks are relatively close together and provide no waiting area for vessels between the locks. In addition, during the peak summer months, the Beauharnois Locks experience more transits by pleasure craft than any other locks due to travel to and from Montreal.

The Welland Canal is located approximately 20 miles west of the Niagara River and connects Lake Erie to Lake Ontario. The canal contains eight locks over a distance of 27 miles that provide a lift of 326 feet between Lake Ontario and Lake Erie. Of the eight locks, Locks 1 through 7 are lift locks, while Lock 8 is primarily a guard lock. Locks 1, 2, 3 and 8 are single locks that handle both upbound and downbound traffic. Locks 4, 5, and 6, called "flights" because they resemble stairs, lift ships a total of 135 feet over the Niagara Escarpment. These locks are twinned, permitting parallel traffic, but each set of three locks is essentially a single-lock system because once a ship enters it must be locked all the way through the three before the next ship is serviced. Lock 7 is considered to be the most constraining lock in the system because of its longer locking time and because of its somewhat curving channel located only about 1800 feet away from the flights.

The Soo lock system consists of four parallel locks, the MacArthur, Poe, Davis, and Sabin Locks. Each lock has its own pier that can accommodate two or three ships in each queue. In addition to the four United States locks, an older lock is located on the Canadian side of the St. Marys River. This lock, however, is small and shallow, and is used primarily by passenger vessels, pleasure craft, and other small ships carrying only a very small amount of cargo. Because of this, the Canadian lock has been excluded from the analysis of Soo Lock capacity.

Currently, the MacArthur Lock handles most of the downbound loaded ships with an overall length of up to 730 feet, but can accommodate ships up to 767 feet in length with special locking procedures. The Poe Lock can process ships up to 1,100 feet in length with a beam of 105 feet, and currently handles mostly "1,000-footers" and all vessels that the MacArthur Lock cannot service. The Sabin and Davis Locks are identical in size and handle most of the ballasted upbound ships having a beam of up to 75 feet and length of up to 826 feet. Because of the shallow depth of both the Sabin and Davis Locks, the number of vessels using these locks has decreased as vessels have either been retired or phased out of the fleets which use the Soo Locks. As a result, only the Sabin or Davis Lock is usually operated unless there is sufficient demand to warrant the operation of both locks.

## 2. THE EXISTING AND FUTURE GREAT LAKES FLEET

This report describes the current Great Lakes fleet and develops an estimate of the future fleet. The fleet mix in future years will depend on the existing fleet structure and the projected requirements for shipping commodities. Many other events will also affect fleet mix, but the most important considerations are economic--fleet building and retirements will follow demand and the economic considerations of vessel operation.

The analysis described in this report involved three steps; each of these steps is described below.

### (1) Interview Program and Data Collection

To develop an understanding of the plans and perceptions of the organizations that will build, purchase, and operate these fleets, interviews with fleet operators, shipbuilding firms, port authorities, shipping associations, and lock operating authorities were conducted. The information developed in these interviews provides a background for the decisions concerning predictions of future fleet mix. The paragraphs that follow give the results of these interviews.

Great Lakes fleet operators have no long-range shipbuilding plans past 1983. When ships are built, they are generally the largest ships that can meet the demands of a particular trade situation. The largest ship possible is not always built, however, because of port limitations.

The smallest ships are not always retired first because some of these ships are needed to serve a particular trade; however, statistics on retirements show that larger ships are likely to remain in service for a longer period of time.

Ships are built for a relatively near-term demand for commodities. A major shift in the demand for the basic commodities that move through the lakes can also be expected to result in a shift in shipbuilding trends. For example, a sudden demand for coal or grain shipments would probably result in more large ships being built to carry these commodities.

There are four major shipbuilding yards in the Great Lakes area, two U.S. and two Canadian. Shipyards are not currently operating near capacity. Although there may sometimes be delays in obtaining ordered ships, in general, shipyard capacity can be expected to expand to meet the demand. Shipbuilders do not believe that winter operations will have a significant effect on a ship's life, but they all admit that operations in ice increase maintenance costs.

(2) Identification of the Current Great Lakes Fleet

Table II-3 shows the current Great Lakes fleet. Bulk freighters and self-unloaders are considered as the primary fleet affecting Seaway system capacity since other principal categories of vessels, tankers and package freighters, are all Class 4 vessels or smaller. These smaller vessels are often only engaged in intralake transport, and therefore these vessels have only a slight impact on the capacity of the system.

The U.S. fleet is primarily composed of Class 5 ships with a length of 600 to 649 feet and a carrying capacity of about 15,000 DWT. The present Canadian fleet is predominantly Class 7 vessels, with a nominal length of 700 to 749 feet and a carrying capacity of about 26,000 DWT. None of the ships in the Canadian fleet are longer than 730 feet since this is the maximum size vessel that can be used in the Welland Canal or the St. Lawrence Seaway.

TABLE II-3
Current Great Lakes Fleet
(Number of Ships)

| Vessel Class | U.S. Fleet | Canadian Fleet | Total |
|---|---|---|---|
| 1 | 0 | 11 | 11 |
| 2 | 0 | 2 | 2 |
| 3 | 1 | 2 | 3 |
| 4 | 8 | 9 | 17 |
| 5 | 77 | 21 | 98 |
| 6 | 12 | 14 | 26 |
| 7 | 10 | 61 | 71 |
| 8 | 13 | 0 | 13 |
| 9 | 1 | 0 | 1 |
| 10 | 10 | 0 | 10 |
| | 132 | 120 | 252 |

Note: Data are for 1980, and include bulk freighters and self-unloaders.
Source: Greenwood's Guide to Great Lakes Shipping.

(3) Estimates of the Future Fleet Mix

Estimates of future fleet mix were based on recent trends in Great Lakes shipbuilding, projected commodity demand and potential physical changes to locks and channels. Recent shipbuilding trends were identified from the interviews described above, and from records showing the current fleet inventory, the annual shipbuilding output, annual ship retirements, and forecasts of shipbuilding requirements. In the last 10 years, most U.S. shipbuilding has been in Class 5 vessels to serve customers in small ports, and in Class 10 vessels to increase the efficiency of operations to large ports. Canadian shipbuilding continues to concentrate on the Seaway Class 7 vessels, with a lower level of construction in the smaller vessels of Class 4 and below.

The procedure used to predict the future fleet mix started by identifying the baseline fleet for a given waterway and lock system from the baseline fleet described above. The baseline fleet for each lock system is shown in Table II-4. If commodity demand was expected to follow current trends, and if no physical changes are made to the system, then additions to the baseline fleet were assumed to follow recent shipbuilding trends. If, however, an unusual

TABLE II-4
Great Lakes/St. Lawrence Seaway Baseline Fleet

| Class | Ore | Coal | Stone | Grain | Other Bulk | General Cargo | Total |
|---|---|---|---|---|---|---|---|
| SOO LOCKS | | | | | | | |
| 4 | 0.0 | 1.4 | .6 | 1.4 | 0.0 | 2.7 | 6.1 |
| 5 | 28.0 | 1.8 | .8 | 3.8 | 1.1 | 0.0 | 35.5 |
| 6 | 2.1 | 5.5 | .1 | 10.4 | 0.0 | 3.8 | 21.9 |
| 7 | 7.5 | .3 | 0.0 | 14.6 | 3.8 | 0.0 | 26.3 |
| 8 | 6.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 6.6 |
| 9 | 1.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 |
| 10 | 2.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 11 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Totals | 47.3 | 9.0 | 1.5 | 30.2 | 4.9 | 6.5 | 99.4 |
| WELLAND CANAL | | | | | | | |
| 4 | 6.1 | 1.0 | 2.0 | 6.9 | .4 | 3.2 | 19.6 |
| 5 | 1.6 | .4 | 2.0 | 5.8 | 1.1 | .5 | 11.4 |
| 6 | 0.0 | 0.0 | 0.0 | 21.0 | 6.4 | 10.1 | 37.5 |
| 7 | 8.2 | 1.5 | .2 | 10.4 | .6 | 0.0 | 20.9 |
| Totals | 15.9 | 2.9 | 4.2 | 44.1 | 8.5 | 13.6 | 89.4 |
| ST. LAWRENCE SEAWAY | | | | | | | |
| 4 | 0.0 | .9 | .3 | 11.2 | 2.8 | 4.2 | 19.4 |
| 5 | 5.7 | .3 | .7 | 4.7 | .4 | .7 | 12.5 |
| 6 | 0.0 | 0.0 | .4 | 22.1 | 7.4 | 11.4 | 41.3 |
| 7 | 6.4 | .5 | .1 | 7.9 | 0.0 | 0.0 | 14.9 |
| Totals | 12.1 | 1.7 | 1.5 | 45.9 | 10.6 | 16.3 | 88.1 |

change was predicted for a particular commodity, then the baseline fleet was expanded with a larger portion of ships built to meet that increased demand. Also, if a system expansion alternative included physical changes to locks and channels, then the program for fleet expansion reflected shipbuilding trends that could be expected as a result of these physical changes. In all cases, ships were added to the fleet to meet commodity demand.

This procedure produced a fleet mix forecast for each lock system for the "non-structural improvement" case, and for each of the structural improvement alternatives.

3. UPDATE OF THE MAXIMUM SHIP SIZE STUDY

The objective of the "Maximum Ship Size Study" was to identify the largest ship which is economically feasible to operate on the Great Lakes system. The maximum feasible ship size is a tradeoff between the increasing benefits of building and operating larger ships, and the increasing costs of improving the system to handle those larger ships.

The purpose of this report was to update the structural and non-structural improvement costs, ship construction costs and required freight rates to January 1981 cost levels. The report consists of a series of tables. The first set contains required freight rates for general cargo and bulk carriers operating at various drafts. The second set of tables presents estimated ship construction costs. The third set of tables describes improvement costs. These are presented in terms of costs for:

- Channel dredging
- Compensating structures
- Locks
- Harbor dredging
- Other related costs.

Costs are provided for alternative lock sizes and channel drafts.

4. EVALUATION OF LOCK CAPACITY MODELS

The attributes of twelve previously developed lock capacity models were reviewed in this report. A multi-step screening process was used to determine which model should be recommended for use in this study. One model, the Welland Canal Lock Model, was dropped from

further consideration primarily because the model is not available, and also because it is an extremely complex, multi-purpose model that is very costly to run.

Since the scope of work for the study required that the lock capacity model be delivered upon completion of the study in standard ANSI FORTRAN, it was judged impractical, in terms of the time and financial constraints imposed upon the program, to redevelop a program written in some other language to FORTRAN. On this basis of programming language, the INSA LOKCAP, and the Penn State MCDD, NETSIM I, and NETSIM/PROSIM models were eliminated from further consideration. Models which were developed for barge-tow applications rather than deep-draft systems were dropped from further consideration since extensive programming revisions would be required to adapt these models to the GL/SLS System. The models which were eliminated on this basis include the WATSIM Model, the LOKSIM Model, and the Bronzini, or LOKSIM II, Model.

Further screening of the remaining four models required a closer investigation of their internal characteristics. In very general terms, the SPAN Model, the Winter Rate Model, and the Sabin-Davis Model were judged to be more complex, and therefore more expensive to run, than is necessary for the purposes of the present study. Consequently it was recommended that the Lock Capacity Model be used for the study of capacity improvement alternatives in this study. The major advantages offered by this model include: execution costs are low, input and output requirements are adequately detailed, the simulation of the locking process is adequate for the purpose of this study, and the programs are well documented and have been validated against actual Soo, Welland and Seaway records.

## 5. LOCK PERFORMANCE AND ALTERNATIVES FOR INCREASING CAPACITY

The objective of this element of the study was to identify lock system performance problems, and to develop and evaluate comprehensive non-structural and structural alternatives for increasing lock capacity. This objective was met by investigating the locking process and the available data on lockage time components; interviewing lakes fleet operators, ocean fleet operators and lock operators regarding existing lock problems; and developing a comprehensive list of capacity expansion alternatives with engineering estimates of the associated performance improvements and costs.

The results of each of these analyses are summarized below.

(1) Locking Processes

The investigation of the locking processes and the available data on lockage time components revealed that there are broad differences in the availability of detailed lockage time data at the three lock systems. Data collected at the Soo Locks are quite limited, consisting only of an arrival time and a departure time. The situation is the same at the Canadian St. Lawrence Locks where, again, only arrival and departure times are recorded. One additional time, the enter time, is recorded at the U.S. St. Lawrence Locks.

In contrast to the situation at the Soo and St. Lawrence Locks, extensive lockage time component data have been collected at the Welland Canal in terms of nine times giving eight time increments. More importantly, the Welland data have been analyzed and condensed into summary form.

The Welland lockage time data therefore serve as a basis upon which to build estimates of lockage time components for all three lock systems, with the resulting total lockage time being determined from the data collected at each lock system. Based upon an analysis of all available data, engineering judgment, and interviews with lock operators, eight lockage time components were estimated for each of the three lock systems with variations due to vessel class and direction of travel.

These estimates are judged to be the best that can be obtained on the basis of the data available. Substantially higher confidence levels could only be realized after one or more years of extensive data collection at the Soo and St. Lawrence Locks in a manner similar to that used at the Welland. The confidence level in the Welland data could be further improved only by additional years of data collection, or the implementation of a totally automated data collection system. Such a system was under consideration for a period of time, but is no longer being actively considered.

(2) Interviews

During peak operation, waiting lines of 20 to 30 vessels are reported at the Soo, and waiting periods as long as five days are reported at the Welland. Lake fleet operators feel that system capacity could be increased substantially by increasing the average

load per transit. Larger locks, wider and deeper channels, and a second Poe-sized lock at the Soo would enable larger ships and more tonnage to pass per transit. These operators also feel that the Coast Guard should not just render assistance to vessels in distress during season extension, but actively maintain open channels with icebreaker operations.

Ocean fleet operators cite draft restrictions as the principal Seaway problem. The requirement for pilots is also cited as causing delays and unnecessary expense. International shippers report waiting lines of 15 to 20 ships at the Welland during peak periods.

(3) Capacity Expansion Alternatives

Seven capacity expansion objectives were defined as follows:

- Reduce time per lockage
- Increase ship capacity
- Increase tonnage per lockage
- Season extension
- Decrease number of lockages
- Construct parallel locks
- Other.

In each category, one or more methods of accomplishing the general capacity expansion objective were identified, producing a total of 24 methods in all. Structural and non-structural methods were considered. Structural improvements involve construction of larger or additional locks, or deeper channels. Non-structural improvements involve achieving more efficient use of the locks without additional construction.

A preliminary screening of these methods was made on the basis of relative cost and capacity increase produced, and some methods were eliminated. The expected performance of each of the remaining alternatives was estimated, and is summarized in Table II-5. Since available data for capacity expansion are limited, ranges have been estimated for each alternative. These ranges represent a quantitative, best engineering judgment on the effect of each alternative.

Table II-6 gives the estimated cost of each of the proposed capacity expansion measures. Detailed cost information is not available for most of the proposed alternatives. The costs given in this study

# TABLE II-5
## Estimated Capacity Improvements

| Expansion Alternative | Operational Parameter | Parameter Change: Soo | Parameter Change: Welland | Parameter Change: Seaway |
|---|---|---|---|---|
| **Reduce Time Per Lockage** | | | | |
| Assist ship into lock: Shunters or mules | Locking time | 0 | - 5-10% | - 0-5% |
| Traveling kevels and winches | Locking time | - 5-10% | - 5-10 | - 5-10 |
| Reduce maneuvering: Approach walls | Locking time | - 0-1 | - 0-4 | - 0-4 |
| | Locking time | - 0-2 | - 0-2 | - 0-2 |
| Wind & wave deflectors | Avail. operating time | + 0-2 | + 0-2 | + 0-2 |
| Increase ship speed | Locking time | - 0-5 | - 0-10 | - 0-5 |
| Decrease chambering time: Reduce dump/fill time | Locking time | - 2-5 | - 2-5 | - 2-5 |
| Downstream longitudinal assistance | Locking time | - 0-4 | - 0-4 | - 0-4 |
| Improve channel | Avail. operating time | + 1-3 | + 2-6 | + 1-5 |
| Improve operating procedures | Locking time | - 1-2 | - 1-2 | - 1-2 |
| **Increase Maximum Ship Size** | Locking time; fleet mix | Max. vessel size | Max. vessel size | Max. vessel size |
| **Increase Tonnage per Lockage** | | | | |
| Favor larger ship | Fleet mix | % of max. size ships | % of max. size ships | % of max. size ships |
| Favor cargo-carrying ships: Eliminate pleasure craft | Non-commercial locking requirements | 0 | +1-2 lockages/day | +1-2 lockages/day |
| Minimize empty backhauls | Fleet mix | No. of ships | No. of ships | No. of ships |
| Discourage oceangoing ships | Fleet mix | Capacity of ship | Capacity of ship | Capacity of ship |
| **Season Extension** | Season length; locking time; fleet mix | 8.5-12 mos. + 0-10 min. | 8.5-12 mos. + 0-10 min. | 8.5-12 mos. + 0-10 min. |
| **Decrease Number of Lockages** | Locking time | 0 | - 20-40% | - 10-30% |
| **Parallel Locks** | Avail. operating time | + 65-100% | + 100-125% | + 100-125% |
| **Other** | | | | |
| Transshipment | Cargo projection | Decrease | Decrease | Decrease |
| Traffic control system | Avail. operating time | + 1-5% | + 1-5% | + 1-5% |

## TABLE II-6
## Estimated Cost of Capacity Improvement
## ($ Million; 1981 Costs)

| Expansion Alternative | Soo | Welland | Seaway |
|---|---|---|---|
| **Reduce Time per Lockage** | | | |
| Assist ship into lock | | | |
| Shunters or mules | - | 200 | - |
| Traveling kevels | 3.8 | 5.0 | 4.4 |
| Winches | 2.5 | 4.9 | 4.3 |
| Reduce maneuvering | | | |
| Approach walls | 19 | 34 | 29 |
| Wind & wave deflectors | 0.5 | 1.0 | 1.0 |
| Increase ship speed | 14 | 19 | 17 |
| Decrease chambering time | | | |
| Reduce dump/fill time | 33 | 62 | 54 |
| Downstream longitudinal assistance | 0 | 0 | 0 |
| Improve channel | 55 | 110 | 250 |
| Improve operating procedures | 1 | 1 | 1 |
| **Increase maximum ship size** | Use the results of the "Maximum Ship Size Study" update in Task 5 | | |
| **Increase tons per lockage** | | | |
| Favor larger ship | 0 | 0 | 0 |
| Favor cargo-carrying ships | | | |
| Alternate pleasure craft lockages | - | 0-80 | 0-80 |
| Reduce empty backhauls | 0 | 0 | 0 |
| Discourage oceangoing ships | 0 | 0 | 0 |

**Season Extension**

| | |
|---|---|
| Proposal 1: | Superior, Huron & Michigan - year round; St. Clair and Erie - 10 mo.; Welland, Ontario & Seaway - 8.5 mo. Investment Cost = 432. |
| Proposal 2: | Superior, Huron & Michigan - year round; St. Clair & Erie - 10 mo.; Welland, Ontario & Seaway - 9 mo. Investment Cost = 505. |
| Proposal 3: | Superior, Huron, Michigan, St. Clair & Erie - year round; Welland, Ontario & Seaway - 8.5 mo. Investment Cost = 708. |
| Proposal 4: | Superior, Huron, Michigan, St. Clair & Erie - year round; Welland, Ontario, & Seaway - 9 mo. Investment Cost = 781. |
| Proposal 5: | Superior, Huron, Michigan, St. Clair & Erie - year round; Welland, Ontario & Seaway - 9.5 mo. Investment Cost = 792. |
| Proposal 6: | Superior, Huron, Michigan, St. Clair & Erie - year round; Welland, Ontario & Seaway - 10 mo. Investment Cost = 810. |
| Proposal 7: | Superior, Huron, Michigan, St. Clair & Erie - year round; Welland, Ontario & Seaway - 11 mo. Investment Cost = 1,004. |

| Expansion Alternative | Soo | Welland | Seaway |
|---|---|---|---|
| **Decrease Number of Lockages** | - | 473 | 235 |
| **Parallel Locks** | 74 | 473 | 520 |
| **Other** | 500 | 500 | 500 |
| Transshipment | | Total system cost = 10 | |
| Traffic control system | | | |

are order-of-magnitude and are for comparative purposes only. However, considering the uncertainties involved in projecting cargo demand and system use criteria through the year 2050, these cost data are judged adequate for this analysis. All of the cost data are expressed in 1981 dollars.

## 6. FEASIBILITY ANALYSIS OF CAPACITY EXPANSION MEASURES

This report documents the results of a sensitivity and feasibility analysis of capacity expansion measures for the Great Lakes/St. Lawrence Seaway System. Non-structural and structural alternatives for increasing the capacity of the system were simulated in an effort to identify possible modifications to the GL/SLS System which would pass the projected 2050 unconstrained commodity flows.

The principal elements of this analysis are described below.

### (1) Use of the GL/SLS Capacity Model

This model was used to perform the lock simulations. The model is a queueing model which analyzes steady-state lock operations and vessel-lock interaction for the Soo, Welland, and St. Lawrence River lock systems. Key input data include the following:

- Time required for a locking operation: The time required for each component of the locking operation was taken from available lock records and conversations with lock operators.

- Fleet mix: This is important since the system constraint is number of lockages per day, and since larger ships carry more cargo per locking operation than smaller ships. The model combines fleet growth projections with projected commodity demand to compute fleet size in future years.

Other input data include vessel and lock operating procedures, length of navigation season and non-commerical vessel locking requirements. For a given set of input data, the model determines the following for fourteen separate time periods (ten months plus early and late April, and early and late December):

- Cargo transported by commodity and direction

- Vessel operating fleet

- Yearly vessel transit demand by vessel class, commodity, and direction
- Daily vessel transit demand by vessel class and direction
- Lock cycle time by direction (mean and standard deviation)
- Average vessel waiting time by direction
- Average vessel queue length by direction
- Lock utilization.

The model performs this analysis every two years from a base year to a prescribed final year. The lock cycle time, average vessel waiting time, average vessel queue length and lock utilization are output for each two-year period, while the results of the entire analysis are output every decade.

The model also determines the year in which capacity is reached based on 90 percent average lock utilization for the months of May through November. The entire output is printed for the capacity year and the model either ends the run for that lock or implements a non-structural or structural capacity expansion measure and continues the analysis until the final year is reached.

The existing model was modified to test for lock capacity, defined as an average lock utilization greater than or equal to 90 percent for the period May through November, and to implement non-structural or structural capacity expansion measures when capacity was reached. Modifications were also made to allow input of up to 15 commodities.

The criterion used for validation of the model was to compare model predictions based on transporting the actual 1976 tonnage with observed lock conditions for 1976 for:

- Number of average daily transits by month
- Distribution of vessel arrivals by vessel class
- Ratio of loaded vessel transits to total vessel transits (if these data were available).

Agreement between the model predictions and actual conditions was quite good and the model accuracy was determined to be adequate for the purpose of this study.

(2) Base Case Capacity

The simulation was run with the lock systems in their existing conditions to determine when capacity would be reached. With existing high water levels permitting drafts of 27 feet at the Soo and 26 feet at the Welland Canal and St. Lawrence River, capacity would be reached in 1984 with 78,926,000 short tons* at the Welland Canal, in 2010 with 182,251,000 tons at the Soo, and in 2014 with 99,174,000 tons at the St. Lawrence River Locks. Using the low water datum draft of 25.5 feet throughout the system, capacity would be reached in 1981 with 75,198,000 tons at the Welland Canal, in 2006 with 173,839,000 tons at the Soo, and in 2006 with 92,526,000 tons at the St. Lawrence River Locks. This second base case (ship draft of 25.5 feet) was used in this feasibility analysis because this is the draft more likely to exist until the year 2050.

(3) Definition of Improvement Alternatives

Four non-structural alternatives were tested for their effectiveness in increasing system capacity. These four alternatives are:

1. Installing traveling kevels (physical assistance to a ship as it moves into a lock)

2. Increasing ship speed into the lock (requiring additional safety procedures and devices)

3. Decreasing chambering time by decreasing dump/fill time, and reducing exit times of downbound ships by providing downstream longitudinal hydraulic assistance (e.g., opening the exit gates before the water level is completely down)

* All references to tons in this report refer to short tons, or tons of 2000 pounds, unless indicated otherwise.

4. Installing a local traffic control system at each lock system in order to reduce delays in lock approaches and to allow faster responses by the lock operators in the locking operation.

A fifth simulation run was made using the combination of these non-structural alternatives which gave the largest locking time reduction. This combination reduced locking times 13 percent and consisted of installing traveling kevels, reducing dump/fill times, and installing local traffic control systems.

Four structural improvement scenarios were modeled to test their ability to pass the projected 2050 unconstrained cargo flows. Two of the scenarios involved constructing larger locks able to pass Class 11 ships and Class 12 ships, respectively. The other two scenarios involved deepening system-wide draft to 28 feet and to 32 feet without changing the existing lock dimensions. Each of the structural modifications was implemented after capacity was reached using the combined non-structural alternatives.

A fifth structural scenario was modeled to determine the effectiveness of constructing another large lock at the Soo without structural modifications to either the St. Lawrence River or the Welland Canal Locks. Cargo flow through the Welland Canal was limited to the near capacity tonnage of 87,400,000 tons achieved with the combined non-structural alternatives. The Soo and St. Lawrence River cargo flows were re-projected based on this constraint. A new lock capable of handling Class 11 ships was built at the Soo when capacity was reached there with the combined non-structural alternatives.

(4) Analysis of Performance of Improvement Alternatives

Tables II-7 through II-15 summarize the results of the analysis of lock capacity expansion alternatives. Each table summarizes a set of runs commencing at the base year of 1978. The non-structural alternative analysis summaries, Tables II-7 through II-10, give the base case, or existing system, capacity conditions and the individual non-structural improvement alternative capacity conditions. The structural alternative analysis summaries, Tables II-11 through II-15, give

TABLE II-7
Results of Lock Capacity Analysis: Non-Structural
Alternative No. 1--Traveling Kevels

| LOCK | CAPACITY YEAR | TONNAGE @ CAPACITY 1000 ST | DELAY[1] TIME hr | COMPOSITE SHIP CLASSES[2] | | | | | | ACTION TAKEN | CAPITAL[3] COST $10^6$\$ | O&M[3,4] COST $10^3$\$/yr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | ORE | COAL | STONE | GRAIN | O.BULK | G.CARGO | | | |
| Soo | 2006 | 173,739 | 21,710d<br>3,284u | 8.3 | 7.7 | 5.1 | 6.6 | 5.3 | 5.7 | Traveling Kevels[11] | 12 | 720 |
| Soo | 2014 | 189,501 | 20,010d<br>4,270u | 8.5 | 7.8 | 6.2 | 6.7 | 5.2 | 5.7 | -- | -- | -- |
| Well | 1981 | 75,198 | 20,052d<br>29,260u | 6.1 | 6.0 | 7.0 | 6.2 | 5.6 | 5.6 | Traveling Kevels[11] | 17 | 1,040 |
| Well | 1985 | 80,738 | 17,140d<br>26,027u | 6.3 | 6.3 | 7.0 | 6.3 | 5.6 | 5.6 | -- | -- | -- |
| SLR | 2006 | 92,526 | 30,508d<br>35,696u | 6.7 | 6.8 | 7.0 | 6.5 | 5.5 | 5.6 | Traveling Kevels[11] | 15 | 910 |
| SLR | 2016 | 100,534 | 28,323d<br>32,329u | 6.7 | 6.7 | 7.0 | 6.6 | 5.5 | 5.6 | -- | -- | -- |

TABLE II-8

Results Of Lock Capacity Analysis: Non-Structural Alternative No. 2--Increase Ship Speed Into Lock

| LOCK | CAPACITY YEAR | TONNAGE @ CAPACITY 1000 ST | DELAY[1] TIME hr | COMPOSITE SHIP CLASSES[2] | | | | | | ACTION TAKEN | CAPITAL[3] COST $10^6$\$ | O&M[3,4] COST $10^3$\$/yr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | ORE | COAL | STONE | GRAIN | O.BULK | G.CARGO | | | |
| Soo | 2006 | 173,739 | 27,310d<br>3,284u | 8.3 | 7.7 | 6.1 | 6.6 | 5.3 | 5.7 | Increase Ship Speed[12] | 2 | 200 |
| Soo | 2008 | 177,988 | 21,356d<br>3,413u | 8.3 | 7.8 | 6.1 | 6.6 | 5.3 | 5.7 | -- | -- | -- |
| Well | 1981 | 75,198 | 20,052d<br>29,260u | 6.1 | 6.0 | 7.0 | 6.2 | 5.6 | 5.6 | Increase Ship Speed[12] | 3.5 | 350 |
| Well | 1984 | 78,921 | 17,603d<br>28,776u | 6.2 | 6.2 | 7.0 | 6.3 | 5.6 | 5.6 | -- | -- | -- |
| SLR | 2006 | 92,526 | 30,508d<br>35,696u | 6.7 | 6.8 | 7.0 | 6.5 | 5.5 | 5.6 | Increase Ship Speed[12] | 3.0 | 300 |
| SLR | 2010 | 96,198 | 32,125d<br>34,272u | 6.7 | 6.7 | 7.0 | 6.6 | 5.5 | 5.6 | -- | -- | -- |

TABLE II-9
Results of Lock Capacity Analysis: Non-Structural
Alternative No. 3--Reduce Chambering Time

| LOCK | CAPACITY YEAR | TONNAGE @ CAPACITY 1000 ST | DELAY[1] TIME hr | COMPOSITE SHIP CLASSES[2] | | | | | | ACTION TAKEN | CAPITAL[3] COST $10^6$\$ | O&M[3,4] COST $10^3$\$/yr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | ORE | COAL | STONE | GRAIN | O.BULK | G.CARGO | | | |
| Soo | 2006 | 173,739 | 21,710d<br>3,284u | 8.3 | 7.7 | 6.1 | 6.6 | 5.3 | 5.7 | Reduce Chamber Time[13] | 41 | 500 |
| Soo | 2010 | 182,250 | 20,794d<br>4,226u | 8.4 | 7.8 | 6.2 | 6.6 | 5.3 | 5.7 | --- | - | - |
| Well | 1981 | 75,198 | 20,052d<br>29,260u | 6.1 | 6.0 | 7.0 | 6.2 | 5.6 | 5.6 | Reduce Chamber Time[13] | 98 | 800 |
| Well | 1983 | 78,839 | 17,988d<br>25,225u | 6.2 | 6.2 | 7.0 | 6.3 | 5.6 | 5.6 | --- | - | - |
| SLR | 2006 | 92,526 | 30,508d<br>35,696u | 6.7 | 6.8 | 7.0 | 6.5 | 5.5 | 5.6 | Reduce Chamber Time[13] | 81 | 800 |
| SLR | 2010 | 96,535 | 19,913d<br>34,596u | 6.7 | 6.7 | 7.0 | 6.6 | 5.6 | 5.6 | --- | - | - |

TABLE II-10
Results of Lock Capacity Analysis: Non-Structural
Alternative No. 4--Local Traffic Control System

| LOCK | CAPACITY YEAR | TONNAGE @ CAPACITY 1000 ST | DELAY[1] TIME hr | COMPOSITE SHIP CLASSES[2] | | | | | | ACTION TAKEN | CAPITAL[3] COST $10^6$\$ | O&M[3,4] COST $10^3$\$/yr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | ORE | COAL | STONE | GRAIN | O.BULK | G.CARGO | | | |
| Soo | 2006 | 173,739 | 21,710d<br>3,234u | 8.3 | 7.7 | 6.1 | 6.6 | 5.3 | 5.7 | Traffic Control[14] | 1 | 100 |
| Soo | 2010 | 182,250 | 21,300d<br>3,754u | 8.4 | 7.8 | 6.2 | 6.6 | 5.3 | 5.7 | --- | - | - |
| Well | 1981 | 75,198 | 20,052d<br>29,260u | 6.1 | 6.0 | 7.0 | 6.2 | 5.6 | 5.6 | Traffic Control[14] | 1 | 100 |
| Well | 1983 | 78,735 | 20,027d<br>29,296u | 6.2 | 6.2 | 7.0 | 6.3 | 5.6 | 5.6 | --- | - | - |
| SLR | 2006 | 92,526 | 30,508d<br>35,696u | 6.7 | 6.8 | 7.0 | 6.5 | 5.5 | 5.6 | Traffic Control[14] | 2 | 200 |
| SLR | 2012 | 97,789 | 32,042d<br>36,007u | 6.7 | 6.7 | 7.0 | 6.6 | 5.5 | 5.6 | --- | - | - |

TABLE II-11

Results Of Lock Capacity Analysis: Scenario No. 1--Non-Structural to Maximum Utility, 1350' x 115' Locks Added at Constrained Sites To Pass Unconstrained Traffic

| LOCK | CAPACITY YEAR | TONNAGE @ CAPACITY 1000 ST | DELAY[1] TIME hr | COMPOSITE SHIP CLASSES[2] | | | | | | ACTION TAKEN | CAPITAL[3] COST $10^6$\$ | O&M[3,4] COST $10^3$\$/yr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | ORE | COAL | STONE | GRAIN | O.BULK | G.CARGO | | | |
| Soo | 2006 | 173,739 | 21,710d 3,284u | 8.3 | 7.7 | 6.1 | 6.6 | 5.3 | 5.7 | N/S to max utility[5] | 48 | 820 |
| Soo | 2018 | 196,766 | 20,386d 5,147u | 8.6 | 7.9 | 6.2 | 6.7 | 5.2 | 5.7 | 1350 x 115 lock[6] | 344 | 421 |
| Soo | 2050 | 272,245 | 21,224d 7,169u | 9.6 | 9.3 | 6.3 | 8.6 | 5.0 | 6.8 | -- | -- | -- |
| Well | 1981 | 75,198 | 20,052d 29,260u | 6.1 | 6.0 | 7.0 | 6.2 | 5.6 | 5.6 | N/S to max utility[5] | 108 | 1,140 |
| Well | 1996 | 88,598 | 17,432d 25,220u | 6.8 | 6.8 | 7.0 | 6.5 | 5.6 | 5.7 | 1350 x 115 locks[6] | 2,081 | 0 |
| Well | 2[illegible]4 | 128,693 | 18,250d 28,869u | 9.2 | 8.4 | 7.0 | 9.1 | 5.6 | 6.6 | -- | -- | -- |
| SLR | 2006 | 92,526 | 30,508d 35,696u | 6.7 | 6.8 | 7.0 | 6.5 | 5.5 | 5.6 | N/S to max utility[5] | 91 | 1,110 |
| SLR | 2024 | 108,597 | 29,994d 31,913u | 6.7 | 6.7 | 7.0 | 6.6 | 5.5 | 5.6 | 1350 x 115 locks[6] | 3,624 | 0 |
| SLR | 2048 | 144,539 | 28,043d 29,684u | 9.3 | 8.7 | 6.5 | 9.3 | 5.5 | 6.6 | -- | -- | -- |

TABLE II-12

Results Of Lock Capacity Analysis: Scenario No. 2--Non-Structural to Maximum Utility, 1460' x 145' Locks Added at Constrained Sites To Pass Unconstrained Traffic

| LOCK | CAPACITY YEAR | TONNAGE @ CAPACITY 1000 ST | DELAY[1] TIME hr | COMPOSITE SHIP CLASSES[2] | | | | | | ACTION TAKEN | CAPITAL[3] COST $10^6$\$ | O&M[3,4] COST $10^3$\$/yr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | ORE | COAL | STONE | GRAIN | O.BULK | G.CARGO | | | |
| Soo | 2006 | 173,739 | 21,710d<br>3,284u | 8.3 | 7.7 | 6.1 | 6.6 | 5.3 | 5.7 | N/S to max utility[5] | 48 | 820 |
| Soo | 2018 | 196,766 | 20,386d<br>5,147u | 8.6 | 7.9 | 6.2 | 6.7 | 5.2 | 5.7 | 1460 x 145 lock[7] | 3,366 | 1,359 |
| Soo | past 2050[8] | 272,247<br>@ 2050 | 14,940d<br>9,726u | 10.2 | 9.5 | 6.2 | 9.8 | 4.9 | 6.8 | -- | -- | -- |
| Well | 1981 | 75,198 | 20,052d<br>29,260u | 6.1 | 6.0 | 7.0 | 6.2 | 5.6 | 5.6 | N/S to max utility[5] | 108 | 1,140 |
| Well | 1996 | 88,598 | 17,432d<br>25,220u | 6.8 | 6.8 | 7.0 | 6.5 | 5.6 | 5.7 | 1460 x 145 locks[7] | 2,456 | 0 |
| Well | 2046 | 148,299 | 18,471d<br>26,520d | 9.8 | 9.0 | 7.0 | 9.8 | 6.7 | 7.0 | -- | -- | -- |
| SLR | 2006 | 92,526 | 30,508d<br>35,696u | 6.7 | 6.8 | 7.0 | 6.5 | 5.5 | 5.6 | N/S to max utility[5] | 91 | 1,110 |
| SLR | 2024 | 108,597 | 29,994d<br>31,913u | 6.7 | 6.7 | 7.0 | 6.6 | 5.5 | 5.6 | 1460 x 145 locks[7] | 4,631 | 0 |
| SLR | past 2050[8] | 148,259<br>@ 2050 | 7,405d<br>7,505u | 9.8 | 9.2 | 6.5 | 9.8 | 6.7 | 7.0 | -- | -- | -- |

TABLE II-13

Results Of Lock Capacity Analysis: Scenario No. 3--Non-Structural to Maximum Utility, Channel Deepening to 30' System Depth, 28' Vessel Draft, Unconstrained Traffic

| LOCK | CAPACITY YEAR | TONNAGE @ CAPACITY 1000 st | DELAY[1] TIME hr | COMPOSITE SHIP CLASSES[2] | | | | | | ACTION TAKEN | CAPITAL[3] COST $10^6$\$ | O&M[3,4] COST $10^3$\$/yr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | ORE | COAL | STONE | GRAIN | O.BULK | G.CARGO | | | |
| Soo | 2006 | 173,739 | 21,710d 3,284u | 8.3 | 7.7 | 6.1 | 6.6 | 5.3 | 5.7 | N/S to max utility[5] | 48 | 820 |
| Soo | 2018 | 196,766 | 20,386d 5,147u | 8.6 | 7.9 | 6.2 | 6.7 | 5.2 | 5.7 | 28 foot draft | 3,284 | 482 |
| Soo | 2026 | 213,734 | 21,988d 5,567u | 8.8 | 7.9 | 6.2 | 6.6 | 5.1 | 5.7 | --- | --- | --- |
| Well | 1981 | 75,198 | 20,052d 29,260u | 6.1 | 6.0 | 7.0 | 6.2 | 5.6 | 5.6 | N/S to max utility[5] | 108 | 1,140 |
| Well | 1996 | 88,598 | 17,432d 25,220u | 6.8 | 6.8 | 7.0 | 6.5 | 5.6 | 5.7 | 28 foot draft | 1,245 | 0 |
| Well | 2012 | 102,558 | 17,291d 25,390u | 6.8 | 6.9 | 7.0 | 6.6 | 5.6 | 5.6 | --- | --- | --- |
| SLR | 2006 | 92,526 | 30,508d 35,696u | 6.7 | 6.8 | 7.0 | 6.5 | 5.5 | 5.6 | N/S to max utility[5] | 91 | 1,110 |
| SLR | 2024 | 108,597 | 29,994d 31,913u | 6.7 | 6.7 | 7.0 | 6.6 | 5.5 | 5.6 | 28 foot draft | 2,974 | 0 |
| SLR | 2034 | 122,945 | 26,527d 29,344u | 6.7 | 6.7 | 7.0 | 6.6 | 5.5 | 5.6 | --- | --- | --- |

TABLE II-14

Results of Lock Capacity Analysis: Scenario No. 4--Non-Structural to Maximum Utility, Channel Deepening to 34' System Depth, 32' Vessel Draft, Unconstrained Traffic

| LOCK | CAPACITY YEAR | TONNAGE @ CAPACITY 1000 ST | DELAY[1] TIME hr | COMPOSITE SHIP CLASSES[2] | | | | | | ACTION TAKEN | CAPITAL[3] COST $10^6$ \$ | O&M[3,4] COST $10^3$ \$/yr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | ORE | COAL | STONE | GRAIN | O.BULK | G.CARGO | | | |
| Soo | 2006 | 173,739 | 21,710d<br>3,284u | 8.3 | 7.7 | 6.1 | 6.6 | 5.3 | 5.7 | N/S to max utility[5] | 48 | 820 |
| Soo | 2018 | 196,766 | 20,386d<br>5,147u | 8.6 | 7.9 | 6.2 | 6.7 | 5.2 | 5.7 | 32 foot draft | 11,410 | 587 |
| Soo | 2038 | 241,652 | 20,115d<br>5,671u | 8.8 | 8.0 | 6.3 | 6.6 | 5.0 | 5.7 | --- | --- | --- |
| Well | 1981 | 75,198 | 20,052d<br>29,260u | 6.1 | 6.0 | 7.0 | 6.2 | 5.6 | 5.6 | N/S to max utility[5] | 108 | 1,140 |
| Well | 1996 | 88,598 | 17,432d<br>25,220u | 6.8 | 6.8 | 7.0 | 6.5 | 5.6 | 5.7 | 32 foot draft | 1,499 | 0 |
| Well | 2030 | 122,586 | 17,778d<br>28,538u | 6.7 | 6.8 | 7.0 | 6.6 | 5.5 | 5.6 | --- | --- | --- |
| SLR | 2006 | 92,526 | 30,508d<br>35,696u | 6.7 | 6.8 | 7.0 | 6.5 | 5.5 | 5.6 | N/S to max utility[5] | 91 | 1,110 |
| SLR | 2024 | 108,597 | 29,994d<br>31,913u | 6.7 | 6.7 | 7.0 | 6.6 | 5.5 | 5.6 | 32 foot draft | 4,158 | 0 |
| SLR | 2046 | 141,885 | 27,084d<br>30,463u | 6.6 | 6.7 | 7.0 | 6.6 | 5.5 | 5.6 | --- | --- | --- |

TABLE II-15

Results Of Lock Capacity Analysis: Scenario No. 5--Non-Structural to Maximum Utility, Then Constrained Cargo Flow due to Welland, 1350' x 115' Lock at Soo[10]

| LOCK | CAPACITY YEAR | TONNAGE @ CAPACITY 1000 ST | DELAY[1] TIME hr | COMPOSITE SHIP CLASSES[2] | | | | | | ACTION TAKEN | CAPITAL[3] COST $10^6$\$ | O&M[3,4] COST $10^3$\$/yr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | ORE | COAL | STONE | GRAIN | O.BULK | G.CARGO | | | |
| Soo | 2008 | 173,483 | 20,854d 3,965u | 8.3 | 7.8 | 6.2 | 6.6 | 5.3 | 5.7 | N/S to max utility[5] | 48 | 820 |
| Soo | 2020 | 191,944 | 22,108d 5,329u | 8.6 | 7.9 | 6.3 | 6.7 | 5.2 | 5.7 | 1350 x 115 lock[6] | 344 | 421 |
| Soo | past 2050[8] | 248,051 @ 2050 | 3,134d 2,204u | 9.4 | 8.8 | 6.3 | 6.7 | 5.0 | 5.7 | -- | -- | -- |
| Well | 1981 | 75,185 | 20,052d 29,260u | 6.1 | 6.1 | 7.0 | 6.2 | 5.6 | 5.6 | N/S to max utility[5] | 108 | 1,140 |
| Well | past 2050[8] | 87,402 @ 2050 | 10,951d 13,829u | 6.6 | 6.7 | 7.0 | 6.6 | 5.5 | 5.6 | -- | -- | -- |
| SLR | 2040 | 92,582 | 30,532d 35,557u | 6.6 | 6.8 | 7.0 | 6.6 | 5.5 | 5.6 | N/S to max utility[5] | 91 | 1,110 |
| SLR | past 2050[8] | 95,429 @ 2050 | 5,594d 5,740u | 6.6 | 6.8 | 7.0 | 6.6 | 5.5 | 5.6 | -- | -- | -- |

## NOTES TO TABLES II-7 THROUGH II-15

1. Delay time is the cumulative waiting time during the capacity year for the constraining lock.

2. Class 6 ships are oceangoing. Class 5 ships are laker classes 5 and 6.

3. Soo Locks costs include the capital or O&M costs of the Soo Locks, the St. Marys River, the St. Clair River, the Detroit River, the Straits of Mackinac, and 17 major Upper Lakes harbors. Welland Canal costs include the capital or O&M costs for the Welland Locks and Canal. St. Lawrence River Locks costs include the capital or O&M costs for the St. Lawrence River and the locks.

4. Operation and maintenance costs given are the additional costs due to the improvements. Zero O&M cost indicates no increase over the no-project level due to the project.

5. N/S to max utility: Non-structural improvements taken to maximum utility consisting of traveling kevels, reduced dump/fill times, and lock traffic control systems. Locking times are reduced 13% in total at each lock system.

6. The 1350 ft x 115 ft lock is capable of passing a 1100 x 105 ft ship (Class 11).

7. The 1460 ft x 145 ft lock is capable of passing a 1200 x 130 ft ship (Class 12).

8. Tonnage, Delay Time, and Composite Ship Class are at 2050.

9. Classes 8 and 9 for the St. Lawrence River and Welland Canal include ocean-going ships longer than 700 feet as well as lakers.

10. Cargos are constrained by the Welland Canal reaching capacity at 1996.

11. Traveling kevels reduce locking times 7.5% at all locks by reducing lock entrance times.

12. Increase ship speed into lock by providing safety bumpers and fenders. Locking time reduced 2.5% at the Soo and St. Lawrence River Locks, and 5.0% at the Welland Canal Locks.

13. Lock Chambering Time decreased by reducing dump/fill and by providing downstream longitudinal assistance. Locking times reduced 5.5% downbound and 1.0% upbound at the Soo and St. Lawrence River Locks, and 5.0% downbound and 2.5% upbound at the Welland Canal Locks.

14. Lock approach times reduced by implementing a local traffic control system. Locking times reduced upbound and downbound 4.5% at the Soo and St. Lawrence River Locks, and 3.0% at the Welland Canal Locks.

15. Vessel draft is 25.5' unless otherwise specified.

the base case capacity conditions, the non-structural alternatives combined to maximum utility capacity conditions, and the structural alternative capacity conditions, or the year 2050 conditions if capacity is not reached by then.

The following information is contained in each of the summary tables:

- Capacity Year: The year in which capacity, defined as an average lock utilization of 90 percent for May through November, is reached. If capacity is not reached by 2050, "past 2050" is specified.

- Tonnage at Capacity: The total amount of cargo processed through the lock system in the capacity year. If capacity is not reached by 2050, the 2050 cargo tonnage is given.

- Delay Time: The total number of ship waiting hours at the constraining lock during the capacity year. This number is obtained by summing over the year for each direction the average vessel waiting time at the constraining lock for each monthly period multiplied by the number of transits during that monthly period. If capacity is not reached by 2050, the 2050 delay times are given.

- Composite Ship Classes: The weighted mean ship class, by commodity, in the fleet utilizing the lock system. If capacity is not reached by 2050, the 2050 composite ship classes are given.

- Action Taken: The capacity expansion alternative that is implemented to relieve the capacity condition.

- Capital Cost: The estimated initial cost of implementing the capacity expansion measure listed in "Action Taken."

- O&M Cost: The estimated additional annual operation and maintenance costs that will be incurred as a result of implementing the expansion measure listed in "Action Taken." A zero under "O&M Cost" indicates that the O&M costs will not increase above existing levels as a result of implementing the alternatives.

## 7. COMPETITIVE POSITION OF THE GREAT LAKES FOR CONTAINERIZED CARGO

This report summarizes historical trends in general cargo shipping on the Great Lakes, and evaluates the outlook for future general cargo shipping. Major conclusions are summarized below.

### (1) Recent Trends

The trend of general cargo foreign trade on the Great Lakes is shown in Table II-16. General cargo shipments via the Great Lakes have averaged growth of about 3.8 percent per year between 1966 and 1977. There have been fluctuations as great as 64 percent from year to year, however.

TABLE II-16
U.S. Great Lakes General Cargo Trade
(Millions of Tons)

| Year | Liner | Non-Liner | Total |
|---|---|---|---|
| 1979 | 1.4 | 6.0* | 7.4 |
| 1978 | 1.4 | 6.0* | 7.4 |
| 1977 | 1.4 | 6.0 | 7.4 |
| 1976 | 1.3 | 3.2 | 4.5 |
| 1975 | 1.1 | 2.5 | 3.6 |
| 1974 | 1.0 | 3.5 | 4.5 |
| 1973 | 2.2 | 3.6 | 5.8 |
| 1972 | 3.2 | 4.7 | 7.9 |
| 1971 | 3.6 | 5.0 | 8.6 |
| 1970 | 3.6 | 2.9 | 6.5 |
| 1969 | 2.4 | 4.6 | 7.0 |
| 1968 | 2.8 | 5.2 | 8.0 |
| 1967 | 4.0 | 2.0 | 6.0 |
| 1966 | 4.1 | 1.4 | 5.5 |

* Estimated.

Source: St. Lawrence Seaway Development Corporation.

Liner service is regularly scheduled general cargo service. Non-liner service is irregular or tramp service. Most steel moves via non-liner service in the Great Lakes, with much of the remaining general cargo moving by liner service. While non-liner

activity has increased steadily since 1966, liner activity declined steadily from 1966 to 1974. The liner tonnage in 1966 was 4.1 million tons and in 1974 it dropped to 1.0 million tons. That change represents a 76 percent decline in tonnage over the nine-year period. Liner tonnage has since stabilized at approximately 1.4 million tons per year.

The decline in liner activity on the Great Lakes has occurred at a time when total U.S. foreign trade liner tonnage was stable, and total U.S. foreign trade (including bulk cargo) through the Great Lakes was increasing.

Since 1966, the quality of liner service in the Great Lakes has deteriorated substantially. Table II-17 presents the number of current and historical liner carriers serving the Great Lakes trades. In 1971, there were 43 liner operators serving the Great Lakes; the Lakes are currently served by only eight scheduled liner services.

(2) Outlook

While the Great Lakes is not a viable market for most direct container vessel services, selected segments, such as heavy lifts, cargoes requiring specialized ships and some low-valued cargo requiring inexpensive transportation, may continue to be shipped via the Lakes.

There are a number of reasons why container shipments by direct vessel service will probably remain at a low level. These are as follows:

- Service quality is poor. Numerous surveys have been conducted to determine the relative importance to shippers of one service or cost factor over another. These surveys indicate that sailing frequency and transit time are more important than transportation costs to container shippers. The quality of service offered in the Great Lakes is substantially poorer than that available from the ocean coasts.

- There is no cost incentive for major liner operators to service the Great Lakes. A cost analysis was performed to determine the

TABLE II-17
Number of Scheduled Liner Carriers Serving
the U.S. Great Lakes, 1962-1980

| Foreign Area | Year | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1962 | 1964 | 1971 | 1972 | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 |
| Europe | 20 | 21 | 11 | 8 | 8 | 5 | 5 | 6 | 6 | 5 | 3 | 2 |
| Mediterranean | 11 | 2 | 5 | 4 | 2 | 3 | 4 | 3 | 3 | 2 | 2 | 2 |
| Far East | 4 | 2 | 7* | 4* | 1 | 4 | 5 | 3 | 2 | 0 | 0 | 0 |
| South & Central America | 2 | 4 | 6 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 |
| Africa | 0 | 1 | 6 | 5 | 3 | 2 | 2 | 3 | 3 | 2 | 0 | 1 |
| Middle East & Australia/ New Zealand | 6 | 2 | 8 | 4 | 2 | 2 | 2 | 3 | 4 | 2 | 2 | 1 |
| Total Number of Liner Carriers | 43 | 32 | 43 | 27 | 18 | 18 | 20 | 21 | 20 | 12 | 9 | 8 |

* Three carriers of the Japanese Consortium were counted as one.

Source: Journal of Commerce and Maritime Administration Office of Trade Studies and Statistics.

comparative cost per TEU* of serving the Great Lakes compared to the East Coast, and is summarized in Table II-18. The carrier's cost per TEU for operating a ship into the Great Lakes is higher than for serving the East Coast, particularly if a larger ship, of the type frequently used in East Coast service, is involved.

TABLE II-18
Carrier Cost per Container

| | Great Lakes (Detroit-Chicago-Rotterdam-Hamburg) | East Coast (New York-Baltimore-Rotterdam-Hamburg) | East Coast (New York-Baltimore Rotterdam-Hamburg) |
|---|---|---|---|
| Vessel Capacity | 660 TEU | 660 TEU | 1,700 TEU |
| Cost per TEU (foreign flag)* | $1,606 | $1,313 | $836 |
| Cost per TEU (U.S. flag, unsubsidized) | $1,767 | $1,366 | $857 |

* Approximately equivalent to subsidized U.S. flag costs.

Note: 90% space utilization.

If the ocean carrier provides an intermodal service to the Great Lakes shipper's door, the all-water route becomes more attractive from a cost standpoint. In this case, the ocean carrier would pay the inland transportation charges and would probably pay some empty container positioning charges. This is illustrated in Table II-19.

For this analysis, Peoria, Illinois, was chosen as representative of the shipper location. The table shows that with full intermodal costs included, the 660-TEU vessel service from the East Coast is more costly than the all-water route. With the 1,700-TEU vessel, however, the East Coast service is still more cost effective.

* Container, twenty-foot equivalent unit.

TABLE II-19
Total Cost per Container
Peoria, Illinois, to Europe

| | Great Lakes Cost (660-TEU Vessel)* | East Coast Cost 660-TEU Vessel | East Coast Cost 1,700-TEU Vessel |
|---|---|---|---|
| Ocean Voyage Cost | $1,606 | $1,313 | $ 836 |
| Rail Cost-Chicago To/From Baltimore | N/A | 575 | 575 |
| Dray Cost-Peoria To/From Chicago | 200 | 200 | 200 |
| Total Door-to-Door | $1,806 | $2,088 | $1,611 |

* Maximum size vessel capable of transiting the seaway.

Note: Ocean voyage costs are based on pro forma operating costs for a foreign flag vessel (approximately equivalent to U.S. flag costs after subsidy), at 90 percent space utilization.

This analysis demonstrates that it is not in the ocean carrier's interest to serve the Great Lakes because of higher operating costs caused by:

- Longer distances in most cases
- Increased voyage days due to distance and seaway transit
- An economy of scale penalty due to operation of smaller vessels and, in many cases, not being able to load full (vessel size and depth restrictions in the locks)
- Limited navigation season causing winter vessel lay-up and operational costs, or additional costs to operate on another route in winter.

- Future regulatory developments will probably not be sufficient to change the competitive position of the Great Lakes. These regulatory developments include rail and truck deregulation and the UNCTAD proposal for flag preference.

A container feeder service appears to be economically feasible, but would not offer competitive service quality. Such a feeder would connect with an oceangoing vessel in Montreal. A pro forma cost analysis of this operation is given in Table II-20. To be competitive, the feeder must have good utilization; the financial analysis indicates that utilization must exceed about 80 percent. The feeder service must have a quick turn time and minimize cargo handling costs. For these reasons, the feeder system would probably not handle non-containerized general cargo.

From a shipper's perspective, the feeder would offer a lower quality of service than is available from the East Coast or from Canadian deepwater ports. The average transit time of the feeder service is seven days compared to two by rail. The frequency of the service is inferior to the rail/water combination service off the East Coast or Canada. Even so, the feeder may be able to attract some segments of the container market.

TABLE II-20
Evaluation of Great Lakes Feeder Service

| | At 55% Utilization (337 TEUs) | At 80% Utilization (490 TEUs) | At 95% Utilization (580 TEUs) | Rail to East Coast Ports |
|---|---|---|---|---|
| Cost per TEU | $663 | $549 | $520 | $550 |
| Average transit time (days) | 7 | 7 | 7 | 2 |

Notes: Based on 306-TEU vessel. Itinerary is Montreal, Detroit, Chicago. Costs include vessel operating and capital costs and 5 percent profit. Transit time is based on one ship, for which the minimum round trip time is 14 days.

## 8. GREAT LAKES INDUSTRY STUDIES

This report describes the industries which control the shipments of most of the traffic using the Great Lakes-- iron ore, limestone, coal, grains and steel. These commodities represent 83 percent of the traffic on the lakes.

Separate reports were prepared for the following industries:

- Grains
- Iron and steel
- Industries consuming steam coal.

A summary of each of these reports is provided below.

### (1) The U.S. and Canadian Grain Industries

The U.S. and Canadian grain industries account for a total of 14 percent of the shipments using the Great Lakes. Each of these industries is described below.

#### 1. The U.S. Grain Industry

This section of the report describes various aspects of the U.S. grain industry with emphasis on factors that are important to grain movements in the GL/SLS.

- Production Patterns

  Substantial amounts of the major grains produced in the United States are exported. The production of each of these grains is concentrated in a few states, and the GL/SLS provides an attractive export outlet for several of these states. Table II-21 identifies production and export levels for major U.S. grains.

  In the last seven years corn has been the leading export grain. In 1978 about 28 percent of the crop was exported, totaling almost 2 billion bushels. Seven states produce almost 80 percent of the corn crop, with Iowa and Illinois accounting for 39 percent of the total. In 1978 wheat exports were 1.2 billion bushels, about 70 percent of production. In previous years exports have usually been about 50 percent of production. About 70

TABLE II-21
U.S. Grain Production and Export
(Million Bushels)

| Grain | Production (1978) | Export (1978) | Percent Exported | Recent Trends |
|---|---|---|---|---|
| Corn | 7,087 | 1,956 | 28% | Exports and percent exported have increased steadily |
| Wheat | 1,798 | 1,246 | 69 | Exports and percent exported have increased slightly |
| Soybeans | 1,870 | 770 | 41 | Exports have increased, percent exported has been relatively constant |
| Barley | 449 | 25 | 6 | Exports and percent exported have declined |
| Rye | 26 | 0 | 0 | Minimal exports |

percent of wheat production is concentrated in eight states, with 41 percent produced by Kansas, North Dakota and Oklahoma.

Soybean exports were about 770 million bushels in 1978, which was about 40 percent of production. Five states are responsible for about 66 percent of soybean production; Iowa and Illinois are also the largest producers.

Barley, rye and sunflower seeds are also produced for export, but the quantities compared to the above grains are much smaller.

- <u>The Grain Marketing Process</u>

Generally, grains move from the farms to local country elevators where the grain is stored until further movement to either a rail terminal or a river terminal. However, there has been an increasing trend toward storage of grain on the farm rather than at the country elevator. Grain is usually moved from the farm by truck to local

country elevators. The movement from country elevators to river or rail terminals is also usually by truck.

In some cases, the farmer sells the grain to the country elevator and his involvement in the marketing process ends. In other cases, the farmer pays for storage at the elevator but still maintains ownership of the grain, and remains involved in further marketing decisions.

The decision-maker, whether it be the farmer, country elevator operator, or a grain merchant, is faced with a set of alternative decisions as to the marketing of the grain:

- The grain can be sold domestically for milling or feed processing.

- The grain can be sold for export.

- The grain can be held in storage, postponing the decision.

The decision to sell for export or domestic consumption is based on a comparison of the prices obtainable from each marketing option, as well as the cost of transporting grain for either domestic or export consumption. The marketing option offering the most attractive financial reward (selling price less cost of transportation) is the marketing option chosen. The marketing decision thus involves not only the choice of the most favorable market location, i.e., export port or domestic geographic market, but also the choice of the most efficient mode of transporting the grain to market location. Changes in prices at any of the stages in the decision process can result in a change in the choice of market location, transportation mode and ultimate decision to sell domestically or export.

Given that an export market decision is made, the choice of port becomes a critical decision. The same factors

that affect the export versus domestic consumption marketing decision also influence the decision as to which port to select for export of grain. A shipper exporting grain evaluates the transportation cost to each alternative export port and the existing export prices (determined by world demand) at these ports. The port is selected that offers the greatest financial return to the shipper.

- Trends in GL/SLS Exports

In general, the Great Lakes ports' share of U.S. grain exports declined in the 1970s, as shown in Table II-22. The exception has been wheat--the Great Lakes' share has fluctuated drastically, and since 1970 has shown a gradual increase.

Most of the grain movements on the GL/SLS are for export. In 1978, 20 percent of the wheat shipments on the lakes were domestic, primarily to Buffalo for milling. Twenty percent of the barley and rye movements in 1978 were also domestic.

The primary grain loading ports on the Great Lakes are Duluth-Superior, Chicago and Toledo. Table II-23 summarizes the important characteristics of each port.

(2) The Canadian Grain Industry

This section of the report provides a profile of the Canadian grain industry, which was responsible for 45 percent of the grain exports shipped via the GL/SLS in 1978.

- Production Patterns

Wheat and barley are the major Canadian grains. The prairie provinces of Manitoba, Alberta and Saskatchewan produce most of the Canadian grains. In 1979 Canada produced 18 million metric tons of wheat and 8 million metric tons of barley. Wheat production has increased since 1970, while barley production has fluctuated widely.

TABLE II-22
Share of U.S. Grain Exports Inspected for Shipments Through Great Lakes/ St. Lawrence Seaway Ports

| | Total | Corn | Wheat | Barley and Rye | Soybean |
|---|---|---|---|---|---|
| | % | % | % | % | % |
| 1970 | 18 | 20 | 9 | 89 | 22 |
| 1971 | 18 | 24 | 9 | 44 | 25 |
| 1972 | 15 | 19 | 10 | 74 | 15 |
| 1973 | 14 | 24 | 10 | 67 | 13 |
| 1974 | 9 | 16 | 6 | 45 | 10 |
| 1975 | 10 | 12 | 12 | 34 | 13 |
| 1976 | 9 | 10 | 6 | 49 | 11 |
| 1977 | 11 | 9 | 12 | 62 | 11 |
| 1978 | 13 | 9 | 16 | 50 | 12 |

Source: Agricultural Marketing Service, USDA, Grain Market News, selected years.

TABLE II-23
Major U.S. Grain-Loading Ports

| Port | 1979 Exports | (Million Bushels) | Extent of Port's Drawing Area | Inland Transportation to Port |
|---|---|---|---|---|
| Duluth-Superior | Wheat | 134 | 500-700 miles | About 50 percent rail, 50 percent truck |
| | Corn | 51 | | |
| | Barley/Rye | 17 | | |
| | Soybeans | 3 | | |
| | | 205 | | |
| Toledo | Corn | 102 | 100-150 miles | Almost all truck |
| | Soybeans | 38 | | |
| | Wheat | 14 | | |
| | | 154 | | |
| Chicago | Corn | 119 | 150-200 miles | About 80 percent truck, 15 percent rail, 5 percent barge |
| | Soybeans | 19 | | |
| | | 138 | | |

- The Grain Marketing Process

  Canadian grain marketing differs significantly from U.S. marketing procedures. The U.S. system consists of several independent producers and buyers, while the Canadian Wheat Board (CWB), a division of the Canadian government, controls the marketing of all Canadian grain. Tne CWB establishes requirements at primary and export elevators, instructs Canadian grain companies to make the appropriate purchases, supplies rail cars for inland transportation, and sets the rail rates.

- Trends in GL/SLS Exports

  The principal Great Lakes port is Thunder Bay, where there are 13 major elevators. In general, shipments from Thunder Bay were greater in the 1970s than in the 1960s. Wheat and barley exports have been increasing gradually, but with significant year-to-year fluctuations. In 1979, lakehead shipments of wheat were 8.4 million metric tons, about 70 percent of Canadian wheat exports. Barley and rye exports in that year were about 2.9 million metric tons, which is also about 70 percent of total Canadian exports.

(2) The Iron and Steel Industry

The Great Lakes iron and steel industry is summarized below.

- The Steelmaking Process

  The first open hearth furnaces in the United States were built in the late 1800s, and for many years were the only type of furnace. Basic oxygen furnaces were used beginning in the 1950s, and are now the dominant type. Electric arc furnaces have traditionally been small and are used for specialty steel products. Large electric furnaces are now being built, and are expected to provide an increasing amount of the nation's steelmaking capacity in the future, as shown in Table II-24.

TABLE II-24
U.S. Raw Steel Capacity By Furnace Type
(Millions of Short Tons)

| Type | 1965 | 1979 | | 2000 | |
|---|---|---|---|---|---|
| BOF | (72%) | 96.8 | (59%) | 111.6 | (54%) |
| Electric | (17%) | 45.5 | (27%) | 92.5 | (44%) |
| Open Hearth | (11%) | 23.0 | (14%) | 6.0 | ( 3%) |
| | 165.3 | 210.1 | | 210.1 | |

Source: The Long-Term Outlook for the U.S. Steel Industry, DRI, 1980.

About 57 percent of Canadian steelmaking capacity uses BOF furnaces, 23 percent uses electric furnaces, and 20 percent uses open hearth furnaces.

The basic raw materials consumed in the production of steel are iron ore, coal, fluxes and steel scrap. In 1979 in the United States, 136.1 million tons of iron ore and agglomerates, 71.7 million tons of coal, 27.3 million tons of fluxes (mostly limestone and lime) and 77.2 million tons of scrap were consumed by the steel industry in the production of 136.3 million tons of raw steel.

Most of the iron ore now mined is a type called "taconite" which contains about 25 percent iron. In order to reduce the cost of shipping waste material to steel plants, such ore is "beneficiated," or upgraded, before shipment. The most common methods are pelletization/magnetic separation and direct reduction through chemical treatment.

Coal supplies more than 80 percent of the steel industry's heat and energy requirements. About 95 percent of the coal is used in coke ovens.

Limestone and lime are used as fluxing agents in blast furnaces, where they combine with undesirable minerals in the ore to produce slag, a waste product.

Steel scrap is an input to the steelmaking process, and the amount consumed depends on furnace type. The electric furnace uses the most, followed by the open hearth and the basic oxygen furnace.

- Production Centers

About 70 percent of American steel production capacity is in areas which use the Great Lakes for transportation of raw materials. Steelmaking capacity in the Great Lakes area is shown in Table II-25.

The Canadian steel industry is concentrated in the province of Ontario, where 70 percent of the country's capacity is located. Major mills are in Hamilton (Dominion Foundries and the Steel Company of Canada) and Sault Sainte Marie (Algonia Steel). Stelco is building a major new plant at Nanticoke, Ontario, on Lake Erie.

TABLE II-25
Steelmaking Capacity in the Great Lakes Area

| District | No. of Facilities | Steel Capacity (000 tons) |
|---|---|---|
| Buffalo | 12 | 4,500 |
| Pittsburgh | 30 | 29,400 |
| Youngstown | 13 | 10,600 |
| Cleveland | 6 | 22,100 |
| Detroit | 6 | 12,800 |
| Chicago | 25 | 42,000 |
| Cincinnati | 10 | 7,400 |

Source: American Iron and Steel Institute

- Industry Outlook

Raw steel production in the Great Lakes area is expected to increase an average of 0.6 percent per year until 1985, about 2.7 percent per year between 1985 and 1990, and about 1.5 percent between 1990 and 2000.*

* The Long-Term Outlook for the U.S. Steel Industry, DRI, 1980

Growth rates for specific steel producing districts are shown in Table II-26.

U.S. imports are expected to take a larger share of the domestic market in the future, rising from around 16 percent of consumption currently to about 20 percent by the year 2000.*

- <u>Supply Sources and Distribution Patterns</u>

The major U.S. sources of iron ore are the Mesabi, Marquette, and Menominee ranges in Minnesota, Wisconsin and Upper Michigan. According to the Bureau of Mines, proven economic reserves from these operating mines will last for 40 to 100 years. Additional reserves not yet "proven" are much greater. This ore is shipped to U.S. steel mills in Lakes Michigan and Erie, and Canadian steel mills at Sault Sainte Marie and Lake Ontario.

TABLE II-26
Forecast Raw Steel Production

| District | (Million Tons) 1979 | 1979-1985 | Rate Growth 1985-1990 | 1990-2000 |
|---|---|---|---|---|
| North East Coast | 15.6 | -0.5% | 3.0% | 0.4% |
| Buffalo | 4.0 | 1.3 | 2.4 | 1.4 |
| Pittsburgh | 24.0 | 0.8 | 2.5 | 1.4 |
| Youngstown | 8.2 | -1.8 | 2.2 | 1.4 |
| Cleveland | 8.7 | 0.3 | 2.6 | 1.2 |
| Detroit | 10.9 | 1.1 | 2.4 | 1.4 |
| Chicago | 32.6 | 1.0 | 2.6 | 1.4 |
| Cincinnati | 5.7 | 1.1 | 2.4 | 1.4 |
| St. Louis | 4.4 | 3.5 | 2.3 | 1.4 |
| Southern | 12.7 | 0.6 | 2.1 | 1.4 |
| Western | 8.7 | -0.2 | 2.8 | 1.4 |
| TOTAL | 135.5 | | | |

Source: <u>The Long-Term Outlook for the U.S. Steel Industry</u>, DRI, 1980.

* <u>The Long-Term Outlook for the U.S. Steel Industry</u>, DRI, 1980

Canadian ore reserves are located in the Lake Superior area and in the northern Quebec and Labrador ranges. These mines supply much of the ore to Canadian steel mills in the Great Lakes, and provide about 20 percent of the ore consumed by U.S. Great Lakes mills.

Captive ownership of raw material sources and transportation equipment is a major factor in the steel industry. Most of the iron ore mines are owned by steel companies, either individually or jointly. Like the mines and the railroads that carry the ore from the mines to shipping ports, many of the American lake vessels are owned by steel companies.

(3) Industries Consuming Steam Coal

The largest coal-consuming sector is electricity generation, which accounts for almost 80 percent of domestic coal consumption nationwide. In states bordering the Great Lakes, 54 percent of generating capacity is coal-fired. In Indiana and Ohio at least 85 percent of generating capacity is coal fired. Many planned generating additions will also burn coal.

There are 62 power plants located within 40 miles of the Great Lakes that burn coal. Most of these are in Michigan, Ohio and Wisconsin.

Almost all coal used by power plants in this country is domestically sourced. While coal is mined in 26 states, more than 75 percent of the nation's reserves are found in six states: Montana, Illinois, Wyoming, West Virginia, Pennsylvania and Kentucky. Appalachian coal is generally classified as medium to high sulfur and high heat content. Midwestern coal (principally from Illinois) is high sulfur, medium to high heat content. Western coal is low sulfur, low heat content.

Power plants usually obtain coal from a variety of sources and blend it to produce a suitable fuel. Most use a mixture of short- and long-term supply contracts as well as spot purchases.

The vast majority of coal shipments on the Great Lakes (84 percent) are loaded at U.S. Lake Erie ports. About half of these shipments are to U.S. ports in the Lower Rivers Area (between Lakes Erie and

Huron), Lake Michigan and Lake Superior. The other half of the shipments loaded in Lake Erie are to Canadian power plants and steel mills in Lakes Erie and Ontario. The port of Duluth/Superior ships to utilities on the St. Clair River and in Marquette, Michigan. Shipments from Chicago have been declining in recent years, and are generally limited to other Lake Michigan destinations.

Most of the shipments described above are controlled by nine utilities representing nineteen power plants. These utilities are all located on the water. Other utilities on the water find it more economical to receive coal by rail.

The trend in the Great Lakes area is toward increased use of Western coal, some of it shipped by water from Duluth-Superior.

Some U.S. coal loaded at Lake Erie ports is transshipped in the St. Lawrence River for overseas destinations. Severe congestion at traditional East Coast U.S. export ports due to increased worldwide coal demand has made such operations feasible. In the long term, as more export capacity is built at East Coast ports, it is not expected that Great Lakes coal exports will remain competitively priced.

## 9. TRAFFIC FORECASTS

This report documents the development of commodity- and lock-specific traffic forecasts. The forecasts are described in three sections:

- Dimensions of the forecasts
- Forecasting methodology
- Forecast results.

These sections are summarized below.

### (1) Dimensions of the Forecasts

The base year on which the forecasts are based is 1978. Base year traffic for U.S. shipments (domestic, U.S.-Canadian, and U.S.-foreign) was based on the dock-to-dock statistics of 1978 Waterborne Commerce of the United States. Since complete port-to-port Canadian traffic (Canadian domestic and Canadian foreign) is not available from Statistics Canada, the

1978 Traffic Report* was used to identify Welland and St. Lawrence Seaway traffic by commodity and direction. The Statistical Report of Lake Commerce Passing Through The Canal at Sault Ste. Marie of the Corps of Engineers identifies Canadian traffic at the Soo Locks by commodity and direction.

Forecasts were developed for 1985, and for every tenth year from 1990 to 2050. More resources were focused on the near-term projections to the year 2000 than on the long-term projections after 2000.

The forecasts contain detail for 15 commodities or groups of commodities. These are shown in Table II-27. In order to evaluate system capacity and benefits of capacity improvements, the detailed forecasts were converted to forecasts for each of the three lock systems--Soo, Welland and St. Lawrence. In addition, the forecasts were aggregated into the following commodity families, as shown in Table II-27:

- Grain
- Coal
- Iron ore
- Limestone
- Other bulk
- General cargo.

The forecasts are unconstrained in the sense that it was assumed that locks, channels and harbors would be adequate to handle the projected traffic. In addition, resource constraints such as acreage or ore/coal deposits were not considered.

(2) Forecasting Methodology

The basic forecasting parameters are shown in Table II-28. The methodology used for each major commodity is summarized below.

1. Grains

About 80 percent of the U.S. grain moving in the GL/SLS is exported, so the discussion below focuses on exports. It is felt that GL/SLS grain exports are influenced primarily by worldwide

* Published by the St. Lawrence Seaway Development Corporation (U.S.) and the St. Lawrence Seaway Authority (Canada).

TABLE II-27
Commodity Detail for Forecasts

| Forecast Level of Detail | Aggregation Used for Capacity Analysis |
|---|---|
| Wheat<br>Soybeans<br>Barley<br>Corn<br>Sunflower seeds | Grains |
| Limestone | Limestone |
| Iron ore | Iron ore |
| Coal | Coal |
| Pigiron, slag, steel scrap<br>Petroleum<br>Cement<br>Non-metallic minerals<br>Other dry bulk | Other bulk |
| Steel<br>Non-steel general cargo | General cargo |

grain supply and demand. The following procedures were employed for corn, wheat, and barley and rye:

(1) Stepwise multiple regression analysis to statistically relate total U.S. exports via the GL/SLS (for each grain) to explanatory variables.* In general, these explanatory factors were total U.S. exports of the grain and stocks in the GL/SLS hinterland states. Historical data were taken from USDA statistics.

(2) Development of forecasts of explanatory variables. Projections of the

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* This procedure statistically relates the time series of historical movements of these commodities on the GL/SLS with time series of explanatory variables affecting the level of movements. Variables are substituted unitl the best curve fit is obtained. Projections of these explanatory variables are then substituted into the established commodity regression relationship in order to project future GL/SLS movements of each major commodity.

## TABLE II-28
## Forecasting Parameters

| Commodity | Explanatory Variables | Direction of Impact on GL/SLS Movements | $R^2$ | F-Statistic |
|---|---|---|---|---|
| Iron ore | U.S. ore production | + | 97% | 53.9* |
| | GL/SLS ore consumption | + | | |
| | Time trend variable | + | | |
| Limestone | U.S. steel production | + | 83 | 40.0* |
| | Limestone consumption | + | | |
| Steel products | Steel imports | + | 99 | 45.0* |
| | Construction employment | + | | |
| | U.S. manufacturing | + | | |
| | Inflation | - | | |
| | U.S. steel production | - | | |
| U.S. wheat | U.S. wheat exports | + | 88 | 34.9* |
| | Stocks in hinterland | + | | |
| U.S. corn | U.S. corn exports | + | 92 | 34.5* |
| | Stocks in hinterland | + | | |
| | Iron ore movements on GL/SLS | + | | |
| U.S. barley and rye | U.S. barley & rye exports | + | 94 | 71.7* |
| | Hinterland stocks | | | |
| Canadian wheat | Total Canadian exports of wheat | + | 87 | 56.0* |
| | Stocks of wheat in Canada | - | | |
| Canadian barley & rye | Total Canadian barley & rye exports | + | 88 | 126.9* |

* Overall equation significant at 95 percent level or above.

explanatory variables were obtained from DRI's The Long-Term Outlook for U.S. Agriculture, November 3, 1980, prepared for the National Waterways Study.

(3) Allocation of GL/SLS forecasts to individual ports. Time series were developed for each port's share of total GL/SLS grain shipments. A future long-term share was then estimated for each port based on these data, and was used to allocate systemwide forecasts to U.S. ports. These port shares were held constant over the forecast period.

No statistical equations were estimated for soybeans and sunflower seeds because of historical data deficiencies. Sunflower seeds movements were projected based on conversations with the Sunflower Association of America and the North Dakota Sunflower Exporters Council. Soybeans were assumed to grow at DRI's future estimated production of soybeans in the United States.

2. U.S. Iron and Steel Raw Materials and Products

Separate forecasts were prepared for iron ore, limestone and steel products. Shipments of these products are directly related to the steel industry in the Great Lakes hinterland states. The following procedure was used:

(1) Stepwise multiple regression analysis to relate GL/SLS shipments to the following explanatory variables:

- Iron ore - ore production in U.S. mines, iron ore consumption by the U.S. steel industry and a time trend variable.

- Limestone - steel production in the GL/SLS states and limestone consumption by the U.S. steel industry.

- Iron and steel products - iron and steel imports from Europe, employment in construction in

GL/SLS states, value added in manufacturing in GL/SLS border states, price index of steel products and steel production in the GL/SLS states.

(2) Development of forecasts of explanatory variables. These were taken from the estimates prepared by DRI for the National Waterways Study, The Long-Term Outlook for U.S. Steel ("Trendlong" Forecasts).

(3) Allocation of forecasts to GL/SLS ports. Time series were developed for each port's share of total GL/SLS receipts of each commodity (1971-1978). The 1978 port share was then compared with the historical average share for each port. The 1978 port share was adjusted, if necessary,to reflect trends in the average historical share.

Each major receiving port was then associated with a steel-producing district (as defined by the American Iron and Steel Institute). The 1978 adjusted port shares were projected to change relative to each other based on DRI's relative growth forecasts of the individual steel districts associated with each port.

### 3. U.S. Coal Movements

Most U.S. coal receipts on the Great Lakes are associated with electricity generation plants. Coal requirements for these plants are determined by generation plans, fuel mix, boiler specifications, environmental regulations, mine price and transportation cost. Twenty-three utilities on the Great Lakes which are now burning coal or which have announced new plants or expansions were surveyed, and planned deliveries and sources for each plant were identified. Each utility plant was associated with a port for receiving coal, and 1978 utility coal receipts versus the total port coal receipts, as reported by the 1978 Waterborne

Commerce Statistics, were compared. Where a utility accounted for all the coal deliveries at a port, the future utility projections were used to describe future coal receipts at that port from specific sources.

When a utility accounted for only a portion of a port's coal receipts, the 1978 sources of coal received at that port were identified from the 1978 port-to-port movements. The utility's coal receipts via the port could be identified with specific movements to that port. These utility-related movements were then replaced with the relevant utility's actual tonnage forecast, and source of future coal receipts.

4. Canadian Grains

Wheat and barley/rye were forecast separately. Multiple regression analysis was used to estimate the statistical relationship between Canadian exports via the GL/SLS and explanatory variables. The explanatory variables for each grain type are:

- Wheat - total Canadian wheat exports and the stocks of Canadian wheat
- Barley and Rye - total Canadian barley and rye exports.

Time series and forecasts of the explanatory variables were obtained from the Canadian Wheat Board. These forecast variables were substituted into separate regression equations to estimate future GL/SLS tonnage of Canadian wheat and barley/rye exports through each of the three lock systems.

5. Canadian Steel Raw Materials and Products

Forecasts of Canadian iron ore movements were based on Canadian studies of these industries and conversations with the major steel mills (Stelco and Dofasco). It is expected that Canadian iron ore movements will increase rather steadily over time at an annual rate of about 1.6 percent.

Canadian steel product movements are estimated to increase quite rapidly during the forecast period due to a 3.3 percent expected annual growth in Canadian industrial production.

Coke movements are estimated to increase by about 2.5 percent annually, which is the average annual long-term growth projected for the Canadian steel industry.

6. General Cargo

General cargo refers to commodities that are distinguishable by "mark and count" techniques. General cargo as discussed in this section excludes iron and steel products, which were described in a preceding section. Almost all of the general cargo shipments moving on the Great Lakes are U.S. imports and exports involving overseas countries.

General cargo shipments on the Great Lakes differ fundamentally from shipments of most bulk cargoes in one key respect. The Great Lakes' "share of the market" of most bulk cargoes is quite high, in that routing via the lakes is generally less expensive than an overland routing. For general cargo, however, the Great Lakes' share of total imports and exports generated by the lakes' hinterland states has traditionally been low. Less than 2 percent of U.S. general cargo foreign trade (excluding steel) moves via Great Lakes ports.

Therefore, when forecasting general cargo shipments, share is much more important than growth of the overall market. The Great Lakes' share cannot be predicted with any confidence by the statistical methods used to forecast bulk commodity traffic. Consequently, judgment-based forecasts were formulated which were consistent with historical data and with expected developments in the competitive position of the Great Lakes system compared to the transportation infrastructure of other North American coasts.

7. Other U.S. Bulk Commodities

Each of the remaining commodities was associated with an explanatory variable it was felt would be likely to affect the movement of that commodity on the GL/SLS. Projections of these explanatory variables by Bureau of Economic Analyis economic areas (BEAs) were obtained from the 1972 OBERS projections developed by the Water

Resource Council. The receiving ports for each commodity were then associated with a BEA, and receipts of the commodities were estimated to grow at the corresponding BEA growth rate for the relevant explanatory variable.

8. Other Canadian Commodities

It was assumed that base year traffic by lock system would grow proportionally to the estimated future annual Canadian population growth rate as estimated by Statistics Canada.

(3) Forecast Results

Figure II-4 shows upbound and downbound unconstrained forecasts for each lock system. Traffic forecasts for each lock system are summarized below.

- Soo Locks - Forecasts for the Soo Locks are shown in Table II-29. More than 90 percent of the cargo moves downbound. This percentage is expected to remain constant over the forecast period. Tonnage is expected to increase an average of 1.3 percent per year in both directions.

  Iron ore is the major commodity moving through this lock system, equaling approximately 63 percent of the total tonnage. The principal movement is downbound from mines in the Mesabi range to steel mills in Lake Michigan and Lake Erie. Export grain comprises another 22 percent of the total. Coal shipments are expected to increase from 7 percent to 12 percent of the total as more Western coal is shipped to power plants in the lower lakes.

- Welland Canal - Forecasts for the Welland Canal are shown in Table II-30. About 70 percent of the cargo moves downbound; this is expected to decrease to about 63 percent by 2050. Tonnage is expected to increase an average of about 1.0 percent per year downbound and about 1.5 percent per year upbound.

  Export grain accounts for about 44 percent of the traffic in this lock system, followed by iron ore (23 percent). About 70 percent

FIGURE II-4
Aggregated Traffic Forecasts
(Uncontainerized)

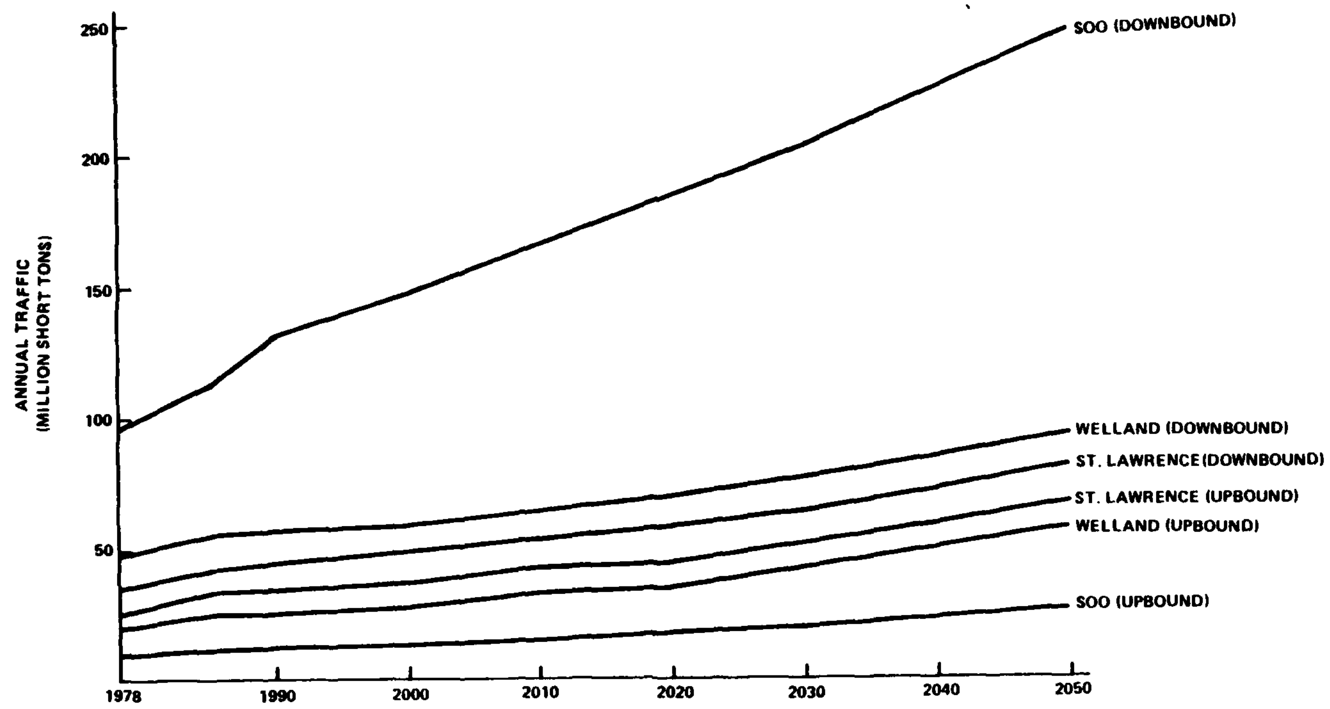


TABLE II-29
Soo Locks Traffic Forecasts
(000 Short Tons)

| | 1978 | 1980 | 1985 | 1990 | 2000 | 2010 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|---|---|
| Downbound | | | | | | | | | | |
| Iron ore | 67,699 | 69,216 | 73,007 | 80,554 | 90,495 | 104,196 | 118,656 | 134,166 | 150,710 | 168,055 |
| Coal | 2,846 | 4,000 | 6,885 | 13,702 | 18,338 | 20,749 | 18,951 | 18,991 | 19,036 | 19,085 |
| Grain | 23,857 | 25,832 | 30,769 | 34,886 | 35,279 | 38,125 | 40,986 | 44,558 | 48,137 | 52,416 |
| Stone | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Other bulk | 1,961 | 2,024 | 2,182 | 2,354 | 2,735 | 3,173 | 3,684 | 4,281 | 4,980 | 5,804 |
| General cargo | 833 | 854 | 907 | 959 | 1,068 | 1,192 | 1,326 | 1,482 | 1,655 | 1,848 |
| Subtotal | 97,196 | 101,926 | 113,750 | 132,455 | 147,915 | 167,435 | 183,603 | 203,478 | 224,518 | 247,208 |
| Upbound | | | | | | | | | | |
| Iron ore | 178 | 183 | 197 | 224 | 254 | 292 | 332 | 375 | 425 | 478 |
| Coal | 4,817 | 5,313 | 6,551 | 5,418 | 6,858 | 7,511 | 8,238 | 9,045 | 9,942 | 10,939 |
| Grain | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Stone | 1,995 | 2,013 | 2,060 | 2,307 | 2,543 | 2,884 | 3,302 | 3,780 | 4,328 | 4,955 |
| Other bulk | 2,475 | 2,553 | 2,749 | 2,953 | 3,471 | 4,063 | 4,782 | 5,654 | 6,718 | 8,017 |
| General cargo | 736 | 764 | 833 | 854 | 943 | 1,056 | 1,141 | 1,303 | 1,469 | 1,651 |
| Subtotal | 10,201 | 10,826 | 12,390 | 11,756 | 14,069 | 15,806 | 17,795 | 20,157 | 22,882 | 26,040 |
| Total | 107,397 | 112,752 | 126,140 | 144,211 | 161,984 | 183,241 | 201,398 | 223,635 | 247,400 | 273,248 |

Note: Traffic is unconstrained by lock conditions.

TABLE II-30
Welland Canal Traffic Forecasts
(000 Short Tons)

| Downbound | 1978 | 1980 | 1985 | 1990 | 2000 | 2010 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|---|---|
| Iron ore | 4,919 | 4,901 | 4,855 | 5,418 | 5,497 | 5,895 | 6,342 | 6,846 | 7,411 | 8,045 |
| Coal | 5,906 | 5,938 | 6,017 | 5,018 | 3,021 | 2,295 | 2,300 | 2,306 | 2,313 | 2,321 |
| Grain | 29,755 | 31,481 | 35,794 | 38,696 | 40,364 | 43,645 | 46,959 | 50,965 | 54,954 | 59,682 |
| Stone | 110 | 110 | 112 | 126 | 139 | 157 | 180 | 206 | 236 | 271 |
| Other bulk | 6,333 | 6,562 | 7,136 | 7,868 | 9,119 | 10,556 | 12,277 | 14,295 | 17,053 | 20,466 |
| General cargo | 1,114 | 1,165 | 1,292 | 1,345 | 1,530 | 1,763 | 1,973 | 2,323 | 2,714 | 3,166 |
| Subtotal | 48,137 | 50,157 | 55,206 | 58,471 | 59,670 | 64,311 | 70,031 | 76,941 | 84,681 | 93,951 |
| Upbound | | | | | | | | | | |
| Iron ore | 11,148 | 11,391 | 12,000 | 13,383 | 15,309 | 17,544 | 19,911 | 22,445 | 25,125 | 28,078 |
| Coal | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Grain | 6 | 7 | 8 | 20 | 23 | 25 | 25 | 25 | 25 | 25 |
| Stone | 46 | 47 | 49 | 55 | 62 | 69 | 80 | 90 | 103 | 119 |
| Other bulk | 3,864 | 3,939 | 4,125 | 4,331 | 4,757 | 5,148 | 5,684 | 6,390 | 7,271 | 8,621 |
| General cargo | 4,792 | 6,209 | 9,750 | 8,250 | 8,711 | 10,621 | 9,069 | 13,454 | 17,221 | 21,117 |
| Subtotal | 19,856 | 21,593 | 25,932 | 26,039 | 28,862 | 33,407 | 34,769 | 42,404 | 49,745 | 57,960 |
| Total | 88,158 | 86,153 | 81,138 | 84,510 | 88,532 | 97,718 | 104,800 | 119,345 | 134,426 | 151,911 |

Note: Traffic is unconstrained by lock conditions.

of the iron ore is from Quebec and Labrador and is shipped upbound, primarily to Canadian steel mills in Lake Erie. Coal is about 9 percent of the tonnage, consisting of U.S. coal shipped from Lake Erie ports to Canadian steel and utility plants on Lake Ontario.

- St. Lawrence Seaway - Forecasts for the seaway are shown in Table II-31. In this lock system, about 58 percent of the cargo moves downbound. This percentage is expected to drop slightly to 54 percent by 2050.

  Tonnage is expected to increase an average of about 1.2 percent per year downbound and 1.4 percent per year upbound. Export grain accounts for about 47 percent of the traffic, and upbound iron ore about 23 percent. Most of this traffic involves the Welland Canal as well.

## 10. RATE ANALYSIS

This report describes the development of a data base of freight rates which forms the basis for estimating the rate savings benefits attributable to lock system improvements.

The collection of component freight rates involved the following steps:

- Identification of port-to-port shipments from Waterborne Commerce Statistics
- Estimation of true origin and destination and specific commodity for these shipments
- Identification of freight rates currently used for these movements
- Establishment of an alternative route for shipment if the Great Lakes system were at capacity and not available
- Estimation of freight rates for these alternative routes.

TABLE II-31
St. Lawrence Seaway Traffic Forecasts
(000 Short Tons)

| Downbound | 1978 | 1980 | 1985 | 1990 | 2000 | 2010 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|---|---|---|
| Iron ore | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Coal | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 3 |
| Grain | 28,745 | 30,409 | 34,570 | 37,295 | 38,816 | 42,010 | 45,153 | 49,006 | 52,841 | 57,391 |
| Stone | 110 | 110 | 112 | 126 | 139 | 157 | 180 | 206 | 236 | 270 |
| Other bulk | 5,501 | 5,708 | 6,226 | 6,939 | 8,126 | 9,491 | 11,086 | 13,094 | 15,633 | 18,915 |
| General cargo | 1,313 | 1,374 | 1,526 | 1,611 | 1,863 | 2,174 | 2,481 | 2,962 | 3,522 | 4,199 |
| Subtotal | 35,670 | 37,602 | 42,435 | 45,972 | 48,945 | 53,834 | 58,902 | 65,270 | 72,235 | 80,778 |
| Upbound | | | | | | | | | | |
| Iron ore | 13,826 | 14,451 | 16,015 | 19,873 | 20,263 | 22,495 | 24,860 | 27,389 | 30,067 | 33,016 |
| Coal | 1,003 | 1,029 | 1,095 | 1,161 | 1,279 | 1,411 | 1,556 | 1,715 | 1,890 | 2,084 |
| Grain | 6 | 7 | 8 | 20 | 23 | 25 | 25 | 25 | 25 | 25 |
| Stone | 46 | 47 | 49 | 55 | 62 | 69 | 80 | 90 | 103 | 119 |
| Other bulk | 5,301 | 5,380 | 5,576 | 5,788 | 6,201 | 6,654 | 7,185 | 7,809 | 8,545 | 9,420 |
| General cargo | 5,592 | 7,036 | 10,647 | 9,231 | 9,861 | 11,963 | 10,648 | 15,325 | 19,459 | 23,822 |
| Subtotal | 25,774 | 27,950 | 33,390 | 36,128 | 37,689 | 42,617 | 44,354 | 52,353 | 60,089 | 68,486 |
| Total | 61,444 | 65,552 | 75,825 | 82,100 | 86,634 | 96,451 | 103,256 | 117,623 | 132,324 | 149,264 |

Note: Traffic is unconstrained by lock conditions.

There are several sources of inaccuracy associated with using actual rates at a single point in time to estimate transportation cost savings.* These are as follows:

- Rates generally fluctuate over time according to market conditions. Recent developments impacting Great Lakes rate levels have included rail deregulation and reduced shipments of iron ore, steel and grains.
- Rates vary significantly depending on weight minimums, actual volume shipped, specific commodity description, origin and destination. There is no way to confirm that a rate extracted from a tariff is the rate at which the goods are shipped.
- Little or no tonnage is currently moving along many of the alternative routes identified for bulk commodities. Rates were estimated for these movements either by railroads directly or by using rates for similar movements. While it is felt that these rates are representative of the rates that would actually be charged, there is no way to validate the rates.

Table II-32 identifies the general sources consulted for rate information. The methods for identification of interior origins and destinations, and for the definition of alternative routes, are summarized below.

TABLE II-32
Sources for Rate Information

| | Published tariffs | Railroads | Lake carriers | Shippers | Barge operators | Industry publications & associations | Other public documents |
|---|---|---|---|---|---|---|---|
| Iron ore | | X | | | | X | |
| Coal | X | X | X | X | | | |
| Grain | | X | | X | X | X | X |
| Other bulk | X | X | X | X | | | X |
| General cargo | X | | X | X | X | | |

* Freight rates for this assignment were collected between the period November 1980 to May 1981.

(1) Iron Ore

Rates from the Mesabi and other Lake Superior ranges are standardized so differentiation of source was not necessary. Destinations were assumed to be waterside except for shipments to steel mills in Pittsburgh, Youngstown and Ashland, Kentucky. The portion of the ore traffic received at Lake Erie ports and destined for these cities was estimated from the 1976 GL/SLS Traffic Forecast Study. Alternative routes are as follows:

| Current Route | Alternative Route |
|---|---|
| Lake Michigan destinations from upper lakes | Rail from upper lakes |
| Other destinations from upper lakes | Labrador ore via coastal ports |
| Labrador ore via the lakes | Labrador ore via coastal ports |

These alternative routes are the next most costly alternative.

(2) Coal

Amost all coal destinations are waterside. Actual movements from specific mines to ports or power plants were identified from FPC Form 423. This provided an indication of the areas providing coal to each port. Weighted mine-to-port rail rates were constructed usually involving the rates from two to five mines.

There are three flow patterns involving Great Lakes locks:

- Lake Erie ports to Lake Superior destinations
- Lake Erie ports to Canadian Lake Ontario destinations
- Western coal via Duluth-Superior to the St. Clair River.

The alternative route for all three is rail from the same mine to point of consumption.

(3) Grain

Grains usually move from farm to export port in a series of successive elevations. At each elevation the grain loses its identity insofar as export grain cannot be traced with certainty to its ultimate origin.

Consequently the drawing area of each port and the location of major transshipment elevators within the drawing area were identified from port personnel and grain merchants. Relative production weights (shares) and modal shares were then identified for each elevator. Then overland sourcing rates were developed which are weighted average rates reflecting the geographic and modal distribution of the major elevators providing grain to each port.

Alternative routes included export via the Atlantic, Gulf and Pacific Coasts and transshipment at the St. Lawrence River. These are currently high-volume routes so existing rates are reasonable.

(4) Other Bulk Commodities

It was assumed that origins and destinations were lakeside; no attempt was made to trace flows to interior points. Alternative routes for lakewise movements were assumed to be via rail between the same points. For exports and imports the commodities were routed through New Orleans or Baltimore, whichever had the lower rate.

(5) Steel and Other General Cargo

No publicly available source identifies interior city of origin or destination and specific commodity for U.S. foreign trade. This information is necessary to identify the actual rates at which most of this traffic moves. A review of several studies indicated that the majority of Great Lakes general cargo foreign trade originates or terminates near the port. It was determined that for benefit calculations it was reasonable to assume that general cargo originates or terminates in Great Lakes port cities. It was felt that this approach would be more realistic than attempting to build up rates from interior points that could not be identified with any confidence.

The source of base year traffic flows (Waterborne Commerce Statistics) does not identify overseas origin or destination. Consequently, weighting factors were established for overseas area and commodity from "U.S. Great Lakes Foreign Trade Statistics," of the St. Lawrence Seaway Development Corporation.

All feasible alternative routes were evaluated, and the route with the lowest total cost was used for the benefit calculation. These routes included shipment via Montreal, Baltimore and New Orleans.

It should be noted that since water freight rates were collected, two liner operators have terminated Great Lakes service and available liner service has been reduced substantially. Consequently the rates collected for this study are no longer representative of current conditions, and would probably overstate the rate savings benefits accruing to Great Lakes shippers for system improvements. In addition, the traffic as identified in the 1978 base year data has probably decreased.

The discussion above described the development of line-haul transportation rates. Total logistics costs, as used in the analysis of benefits of lock system improvements, include terminal/handling costs, seaway tolls (if applicable) and inventory carrying cost. Terminal and handling costs were included only when the Great Lakes route involved a different number of intermodal transfers than the alternate route. Seaway tolls were not included because the impact on total logistics cost was negligible.

Finally, a measure of the value of goods in transit, or inventory carrying cost, was developed for major commodity groups. The purpose of this analysis was to determine the extent to which differences in average transit time between Great Lakes routes and the next most expensive route will impact net benefits.

The only major commodities for which this difference is expected to be at all significant are grain, iron ore and general cargo. Table II-33 shows the value of the time penalty for a Great Lakes route and average rate differentials. This penalty was added to the Great Lakes rate before rate savings benefits were calculated.

TABLE II-33
Inventory Carrying Cost

| Commodity | Average Rate Savings* ($/NT) | Inventory Carrying Cost ($/NT) | Net Rate Savings ($/NT) |
|---|---|---|---|
| Iron ore | $5.00-7.54 | $0.02 | $4.98-7.52 |
| Grain | 2.23-3.58 | 0.67 | 1.56-2.91 |
| General cargo excluding steel | 31.57 | 10.95 | 20.62 |

* Excluding inventory carrying cost.

# III. BENEFIT-COST METHODOLOGY

## III. BENEFIT-COST METHODOLOGY

The preliminary feasibility analysis of system capacity improvements is based on a benefit-cost analysis. This chapter describes the methodology used for the benefit-cost analysis, and includes illustrations of sample calculations.

### 1. BENEFITS

The method for calculating benefits is described below. For purposes of explanation, certain aspects of structural improvement Scenario No. 3 (30-foot system draft) are used to illustrate how the benefits are calculated. In this scenario, capacity is reached at the Soo Locks in 2006 at 173,739,000 tons. The composite iron ore ship class at this time is 8.3, and the cumulative delay time at the lock in 2006, when the lock is at capacity, is 24,994 hours over the entire year. Non-structural improvements are implemented to maximum utility, and this postpones reaching capacity until 2018. At this time cumulative delay time would be 25,533 hours, and the tonnage would be 196,766,000 tons. The average ore ship class at this time is 8.6. The channel is then deepened to 30 feet (permitting 28-foot vessel draft), which postpones reaching capacity until 2026. The average ore ship class has increased to 8.8 by 2026.

Only U.S. benefits are included in the analysis. All of the benefits for U.S. domestic and overseas foreign trade were included. Fifty percent of the benefits for U.S.-Canadian trade were included, and none of the benefits for Canadian domestic and Canadian foreign trade were included.

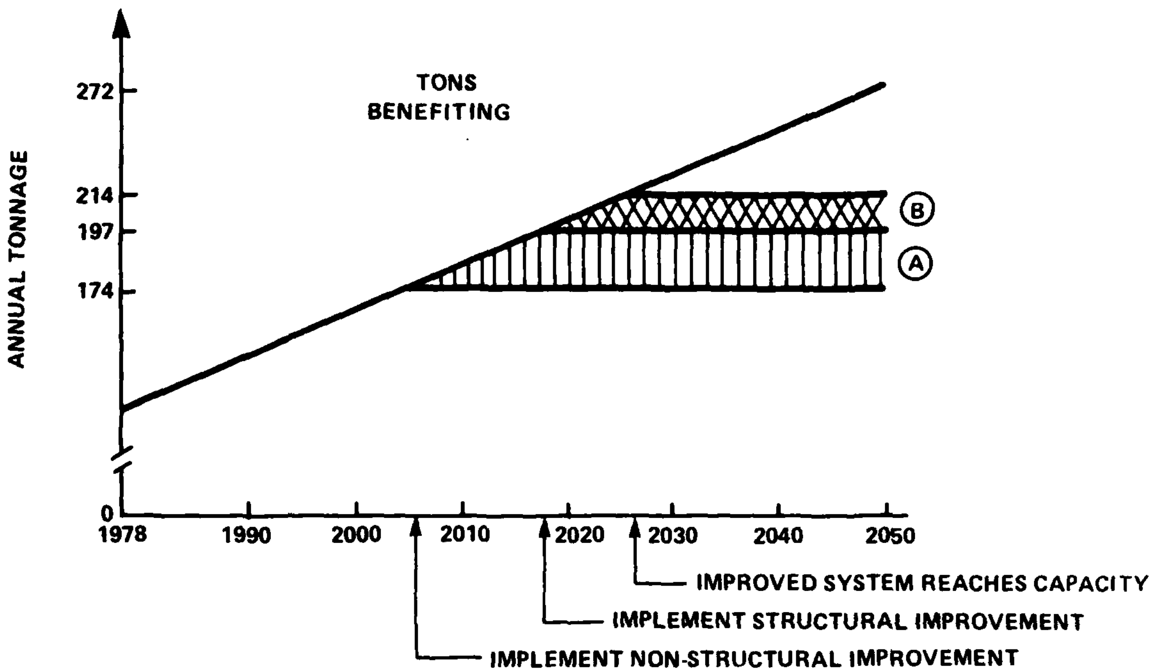
The method for calculating each type of benefits is as follows:

- Rate Savings Benefits. These benefits accrue to each ton which is able to use the system after it would otherwise have reached capacity. The savings per ton is the difference between the

freight rate for a Great Lakes route and the freight rate for the next most expensive transportation alternative.

Figure III-1 shows the tons which receive these benefits. Accrual of rate savings starts in the first year after the project year, and continues until 2050.

FIGURE III-1
Tonnage Receiving Rate Savings Benefits




NOTE:

(A) TONS WHICH ARE ABLE TO USE THE SYSTEM BECAUSE OF NON-STRUCTURAL IMPROVEMENTS.

(B) TONS WHICH ARE ABLE TO USE THE SYSTEM BECAUSE OF STRUCTURAL IMPROVEMENTS.

The rule for determining which shipments would be diverted from the lakes if capacity were reached is that all tons have an equal elasticity to increases in delay and cost, and therefore the cargoes which cannot use the system are the increases which were forecast over and above the tonnage at capacity.

The tons receiving benefits from non-structural improvements are the additional tons which would have been added to the system between 2006 and 2018. The benefit these tons receive is saving the rate penalty they would have to pay if forced off the system to a more expensive transportation mode and route. The tons receiving benefits from structural improvements are the tons which would have been added between 2018 and 2026.

After capacity is reached, if the tonnage for a given port pair falls below the tonnage at the year capacity was reached, the tonnage for all other port pairs is not adjusted upward. This means that traffic through the lock may fluctuate slightly below capacity.

Rate savings benefits are calculated for each port pair movement. For example, for iron ore, there are 60 port pair movements involving at least one U.S. port. Rates were collected for 44 of these movements, which accounted for 88 percent of the tonnage. The rate savings benefits for these 60 movements are the rate differential for each movement multiplied by the tonnage. The weighted average rate differential was $4.97 per ton. This rate differential was applied to the remaining 12 percent of the tonnage.

Occasionally the transportation cost for the alternative route is less than that for the Great Lakes route. These are situations where the freight rates do not reflect the total logistic cost of the movement. This could be caused by:

- Ownership of supply source (e.g., iron ore or coal mine)
- Ownership of transportation equipment or terminals
- Long-term supply contracts.

These factors could easily make the current Great Lakes route more attractive than others. In these cases no transportation savings are claimed, and the traffic continues to use the lock after improvements. It is expected that this traffic would ultimately leave the lake system after major capital investments for mine or transportation equipment ownership are made.

- Savings From Reduction in Lock Delays. Vessel delays at a lock system which is operating well below capacity are negligible. As a capacity condition is approached, delays will increase relatively slowly until a congested condition (at around 90 percent lock utilization) is reached. Beyond 90 percent utilization, congestion and waiting time increase rapidly.

  Figure III-2 illustrates this condition at the St. Lawrence River locks. The information is based on execution of the Lock Capacity Model. In Case "A" the St. Lawrence River locks are improved as in structural improvement Scenario No. 1. Delays increase until capacity is encountered in 2006 and then are reduced when non-structural improvements are implemented. Delays again increase until capacity is encountered in 2024, and then are reduced when structural improvements are made. For the purpose of estimating delay benefits for the non-structural improvement, without-project condition, delay was assumed to be zero before 2006 and equal to 65,000 hours after 2006 (assuming no more traffic can use the lock after 2006). The with-project delay is assumed to be zero.

  Case "B" in the figure illustrates delay time if improvements are made in 1996, well before capacity is reached, to coincide with Welland Canal improvements. The without-project delay is as above; the with-project delay is again assumed to be zero. This example illustrates that delay benefits for Case "B" may be slightly understated.

  Figure III-3 illustrates how delay benefits are calculated. For non-structural improvments, the without-project condition involves a delay for each ship using the lock system at maximum utilization between 2006 and 2018. Since delay time is relatively small almost until capacity is

FIGURE III-2
Delay Time at St. Lawrence River Locks

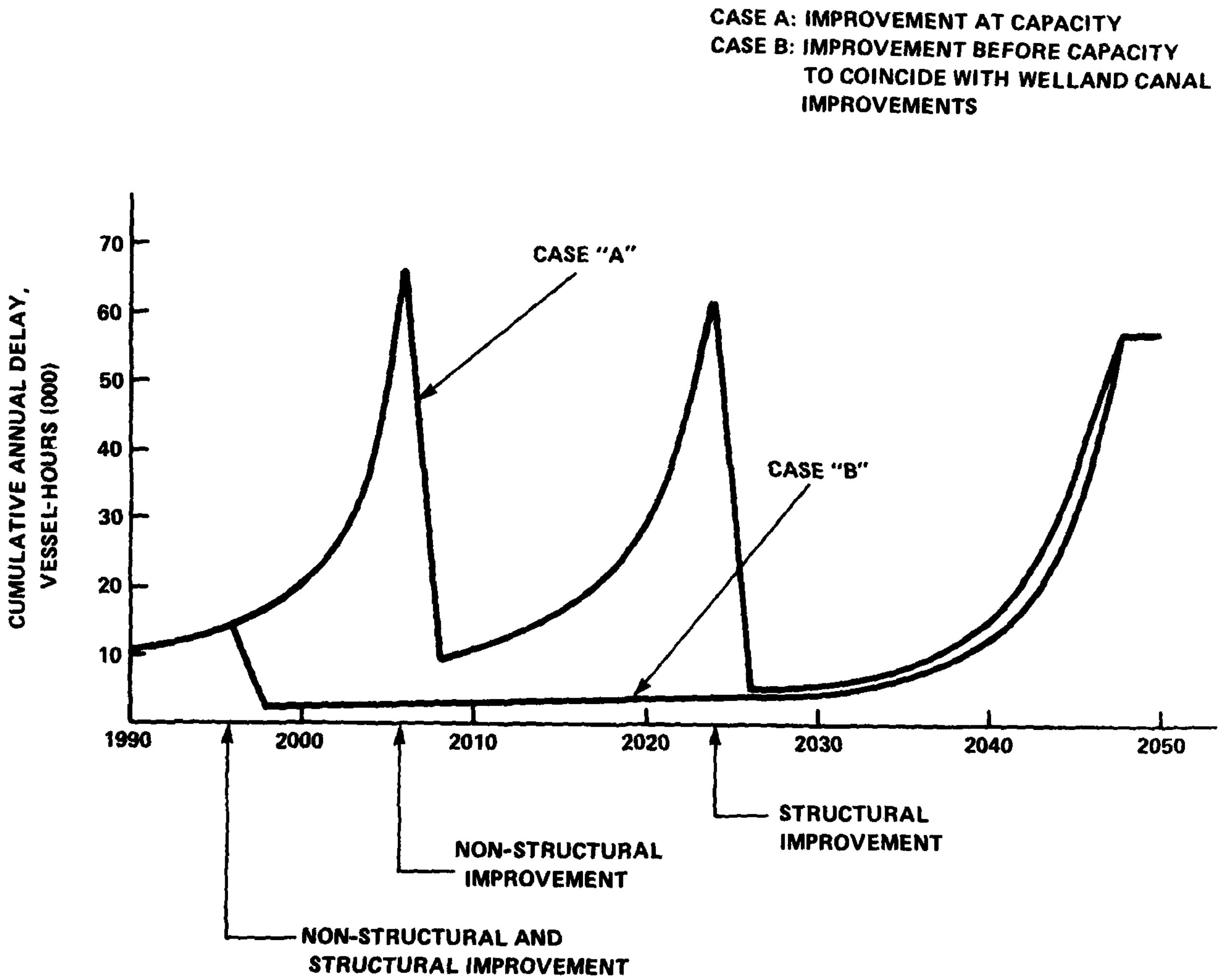
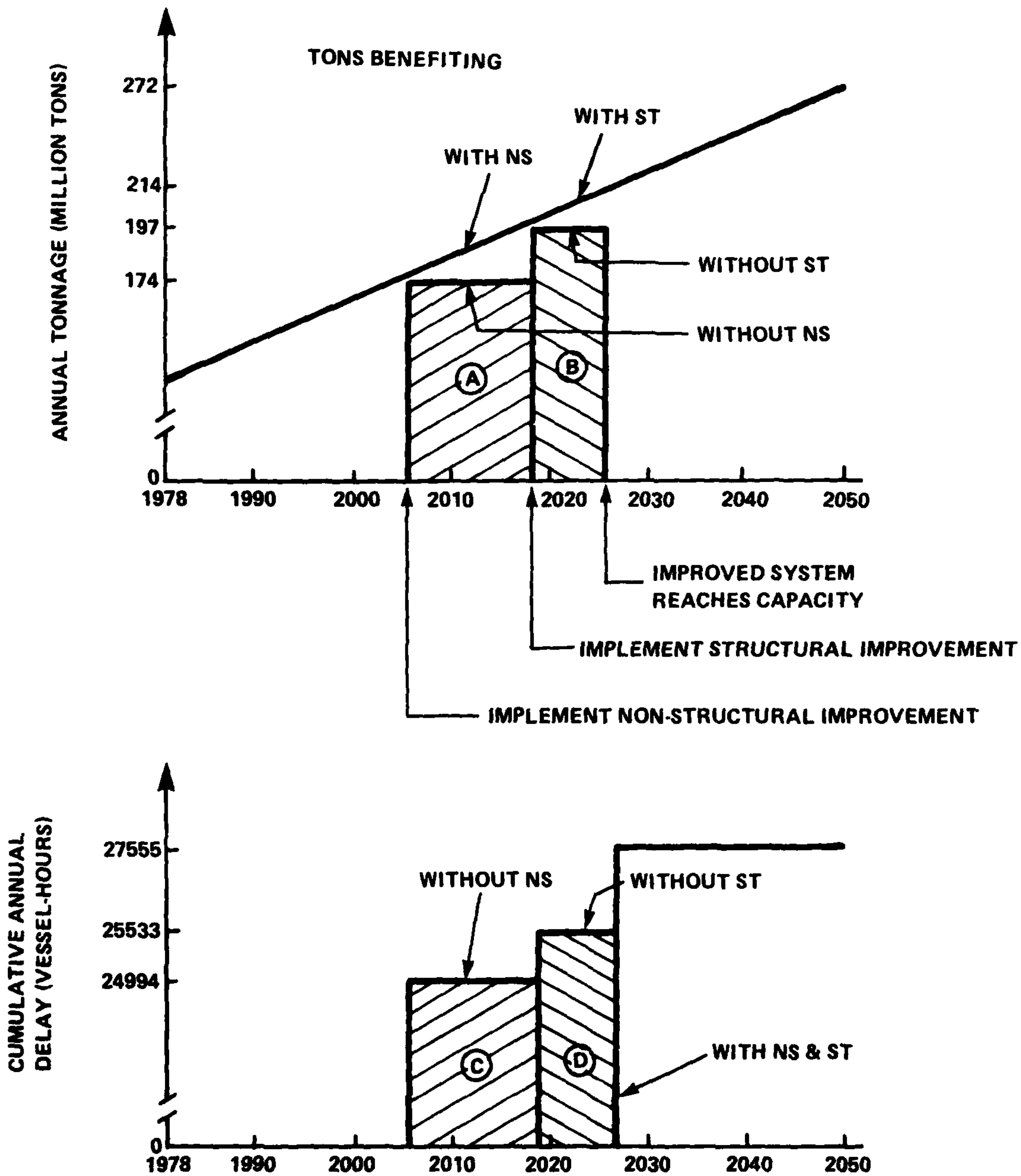


FIGURE III-3
Benefits From Reduction in Lock Delays




NOTE: NS BENEFITS: (A) TONS, (C) HOURS

ST BENEFITS: (B) TONS, (D) HOURS

reached, cumulative annual delay is assumed to be zero before 2006 and a total of 24,994 hours per year after 2006. The tons experiencing a delay are the without-project tons ("A" in the figure).

The with-project condition postpones these delays until the system would have reached capacity in 2018. The benefit is the cost of the delay avoided during the intervening years, which is a function of hourly ship operating costs. Ship operating costs are determined by calculating the average ship class for each commodity group. For iron ore this will vary between 8.3 (in 2006) and 8.6 (in 2018).

Hourly operating costs for each ship class are shown in Table III-1. The costs used for calculation of delay savings include capital and operating costs, plus overhead and profit. Operating costs reflect operations at one-third the normal fuel consumption rate, which approximates fuel consumption while waiting at a congested lock.

A weighted average cost per hour is calculated by taking the cost per hour for each commodity group, weighted by the tonnage of each commodity group using the lock. Delay savings in each year are equal to this weighted average hourly vessel cost, multiplied by the cumulative delay in each year (24,994 hours).

A check was made to confirm that delay savings (i.e., the waiting time penalty to use the system) never exceeds the rate savings (i.e., the penalty of using a more expensive route). In such cases the lower measure of benefit was claimed for delay savings.

- Vessel Utilization Savings. These savings are the results of structural improvements to the system. For improvements involving larger locks, the savings are associated with the use of larger ships, which in turn result in increased efficiency of operation and a lower per-ton freight rate. For improvements involving deeper channels, the savings result from loading some of the larger ships with more cargo and operating at deeper drafts. This also increases operating efficiency and produces a lower freight rate.

TABLE III-1
Vessel Operating Cost Data

| Line | Cost Element | Vessel Class 5 | 6 | 7 | 8 | 9[1] | 10 | 11 | Source |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Construction cost ($ million) | $30 | $33 | $37 | $41 | $53 | $64 | $74 | (2) |
| 2 | Annualized capital cost ($000) | 2,347 | 2,582 | 2,895 | 3,207 | 4,107 | 5,007 | 5,789 | (3) |
| 3 | Equivalent capital cost per hour | 362 | 398 | 447 | 495 | 634 | 773 | 893 | (4) |
| 4 | Hourly operating cost (normal operation) | 595 | 641 | 663 | 699 | 798 | 897 | 970 | (5) |
| 5 | Hourly operating cost (while waiting at lock) | 403 | 425 | 437 | 459 | 515 | 571 | 612 | (6) |
| 6 | Total hourly operating cost (while waiting) | 935 | 1,005 | 1,077 | 1,160 | 1,392 | 1,624 | 1,815 | (7) |

(1) Interpolated from Classes 8 and 10 since there is only one Class 9 vessel in the fleet and costs are probably not representative.

(2) "Great Lakes Bulk Vessel Operating Costs," U.S. Maritime Administration (Costs as of December 14, 1979). Wages effective June 1979; fuel cost as of November 1979 of $32.34 per barrel (diesel).

(3) Annual principal and interest payment at 7 5/8 percent for 50 years.

(4) For 270-day season, 24 hours per day.

(5) Daily vessel operating expenses [source (1)], divided by 24 hours per day.

(6) Line (4) but at 1/3 fuel consumption rate at sea to represent fuel consumption cost while waiting.

(7) Line (5) plus 12 percent of line (5) for overhead, plus line (3), plus 15 percent profit.

Figure III-4 illustrates how these benefits are calculated. All of the tons using the system benefit, as shown in the figure. Between 2018 and 2026 the vessel class for ore increases from 8.6 to 8.8 and remains constant after that. Figure III-5 shows the required freight rate for ore ships as a function of vessel class and system draft.

Required freight rates are based on capital and operating costs, and a measure of overhead costs and profit. Thus vessel utilization savings are based on cost rather than actual freight rates. Note that the freight rate for a Class 5 ship is independent of draft because these ships will not draw more than 25.5 feet at full utilization.

Tables III-2 through III-4 show required freight rates at the other lock systems at drafts of 25.5, 28 and 32 feet. The freight rates at 28 and 32 feet are the same for the most part because draft at capacity for Class 10 ships and below is no greater than 28 feet. Thus a system draft greater than 28 feet allows only Class 11 vessels and above to be loaded with additional cargo.

These required freight rates were calculated as follows. Table III-5 shows average one-way mileage and speed for different commodities and lock systems. This information was used to determine numbers of annual trips. Average utilization, from this table, and ship capacity and immersion factors for each vessel class (from Table III-6) were then used to estimate annual cargo carried for each vessel class, commodity and lock system. This information was then combined with annual capital and operating costs as shown in Table III-7 to produce required freight rates. These calculations are as follows:

$$\text{One-way trips per year} = \frac{(\text{speed}) \times (6{,}480 \text{ hours/yr})}{(\text{one-way miles})}$$

$$(\$/\text{ton}) = \frac{(\text{annual cost})}{\begin{pmatrix}\text{one-way}\\ \text{trips/yr}\end{pmatrix} \times \begin{pmatrix}\text{tons}\\ \text{capac.}\end{pmatrix} \times \begin{pmatrix}\text{avg}\\ \text{util.}\end{pmatrix}}$$

Figure III-4 showed how the preceding information is combined to determine how required freight rates will change between 2018 and 2050. The

FIGURE III-4
Vessel Utilization Savings

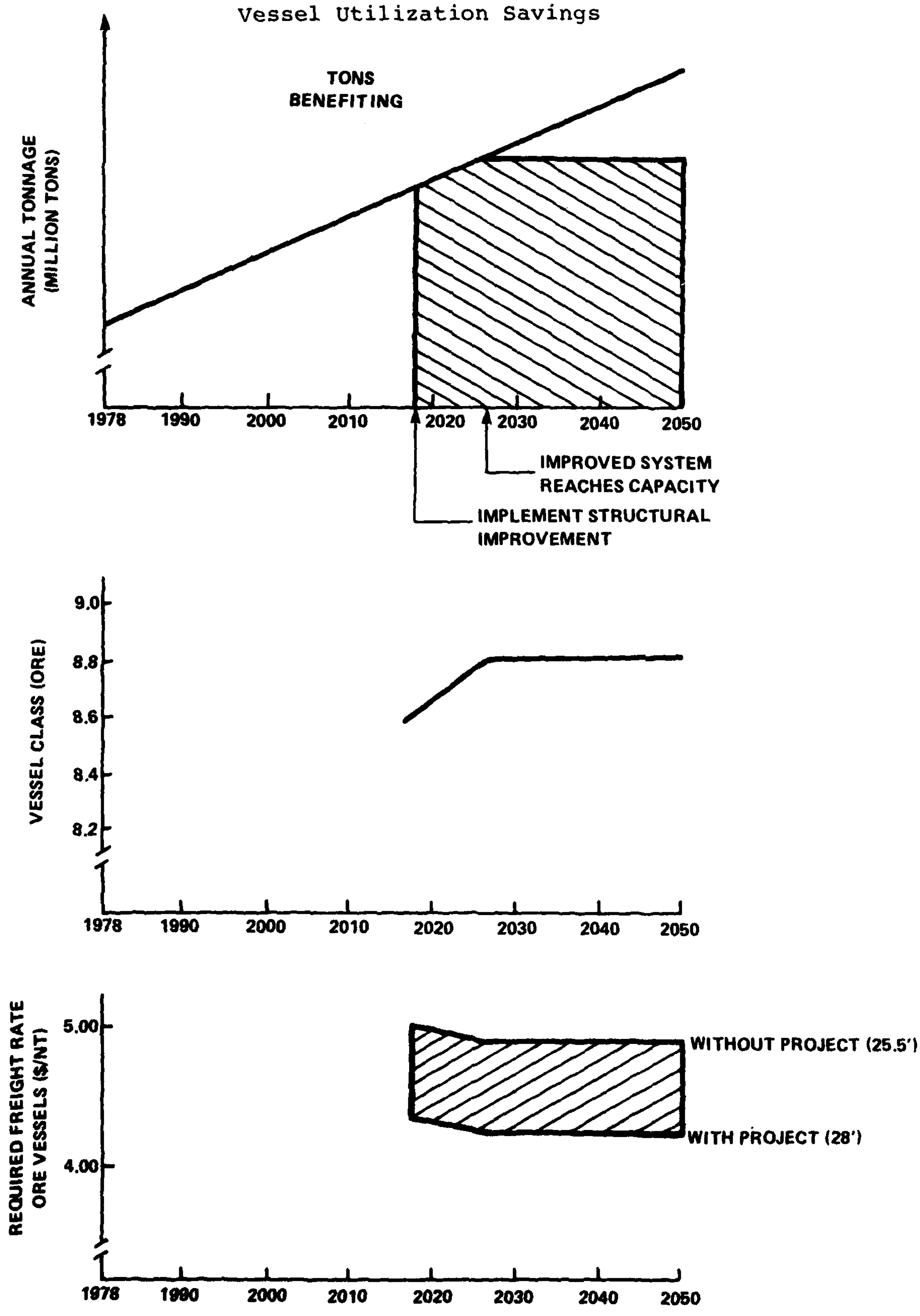


FIGURE III-5
Required Freight Rate Relationship

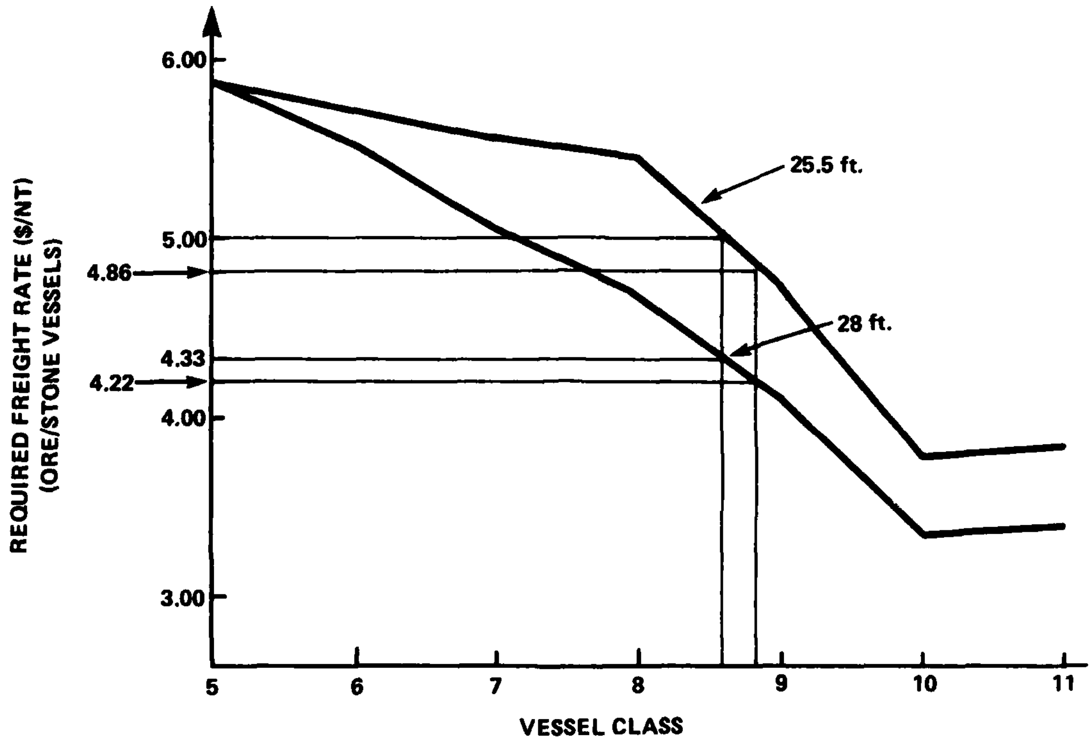


TABLE III-2
Required Freight Rates--
Soo Locks Fleet
($/Short ton)

MAXIMUM DRAFT: 25.5 Feet

| | Vessel Class | | | | | | |
|---|---|---|---|---|---|---|---|
| | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| Iron ore | 5.83 | 5.74 | 5.57 | 5.43 | 4.61 | 3.78 | 3.82 |
| Coal | 4.91 | 4.92 | 4.87 | 4.84 | 4.08 | 3.31 | 3.44 |
| Grain | 13.40 | 13.43 | 13.30 | 13.22 | 11.14 | 9.05 | 9.39 |
| Stone | 5.59 | 5.51 | 5.34 | 5.21 | 4.42 | 3.63 | 3.66 |
| Other bulk | 6.73 | 6.75 | 6.68 | 6.64 | 5.60 | 4.55 | 4.72 |
| General cargo | 4.95 | 4.96 | 4.91 | 4.88 | 4.11 | 3.34 | 3.47 |

MAXIMUM DRAFT: 28 Feet or 32 Feet

| | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|
| Iron ore | 5.83 | 5.46 | 5.02 | 4.67 | 4.02 | 3.36 | 3.40 |
| Coal | 4.91 | 4.62 | 4.25 | 3.97 | 3.41 | 2.84 | 2.95 |
| Grain | 13.40 | 12.60 | 11.61 | 10.84 | 9.31 | 7.78 | 8.05 |
| Stone | 5.59 | 5.25 | 4.81 | 4.48 | 3.86 | 3.23 | 3.26 |
| Other bulk | 6.73 | 6.33 | 5.83 | 5.45 | 4.68 | 3.91 | 4.05 |
| General cargo | 4.95 | 4.65 | 4.28 | 4.00 | 3.44 | 2.87 | 2.97 |

TABLE III-3
Required Freight Rates--
Welland Canal
($/Short ton)

| | Vessel Class | | | | | | |
|---|---|---|---|---|---|---|---|
| | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| **MAXIMUM DRAFT: 25.5 Feet** | | | | | | | |
| Iron ore | 4.87 | 4.80 | 4.55 | 4.54 | 3.85 | 3.16 | 3.19 |
| Coal | 2.74 | 2.74 | 2.72 | 2.70 | 2.28 | 1.85 | 1.92 |
| Grain | 11.93 | 11.96 | 11.83 | 11.78 | 9.92 | 8.06 | 8.36 |
| Stone | 2.14 | 2.11 | 2.05 | 1.99 | 1.69 | 1.39 | 1.40 |
| Other bulk | 3.60 | 3.61 | 3.57 | 3.55 | 2.99 | 2.43 | 2.52 |
| General cargo | 6.96 | 6.98 | 6.91 | 6.87 | 5.79 | 4.70 | 4.88 |
| **MAXIMUM DRAFT: 28 Feet or 32 Feet** | | | | | | | |
| Iron ore | 4.87 | 4.56 | 4.19 | 3.90 | 3.36 | 2.81 | 2.84 |
| Coal | 2.74 | 2.58 | 2.37 | 2.21 | 1.90 | 1.59 | 1.65 |
| Grain | 11.93 | 11.24 | 10.29 | 9.66 | 8.30 | 6.93 | 7.19 |
| Stone | 2.14 | 2.00 | 1.85 | 1.71 | 1.48 | 1.24 | 1.25 |
| Other bulk | 3.60 | 3.39 | 3.11 | 2.91 | 2.50 | 2.09 | 2.17 |
| General cargo | 6.96 | 6.56 | 6.01 | 5.63 | 4.84 | 4.04 | 4.20 |

TABLE III-4
Required Freight Rates--
St. Lawrence Seaway
($/Short ton)

MAXIMUM DRAFT: 25.5 Feet

| | Vessel Class | | | | | | |
|---|---|---|---|---|---|---|---|
| | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| Iron ore | 6.43 | 6.34 | 6.14 | 5.99 | 5.08 | 4.17 | 4.21 |
| Coal | 2.74 | 2.74 | 2.72 | 2.70 | 2.28 | 1.85 | 1.92 |
| Grain | 11.93 | 11.96 | 11.83 | 11.78 | 9.92 | 8.06 | 8.36 |
| Stone | 2.14 | 2.11 | 2.05 | 1.99 | 1.69 | 1.39 | 1.40 |
| Other bulk | 3.16 | 3.17 | 3.13 | 3.12 | 2.63 | 2.13 | 2.21 |
| General cargo | 6.96 | 6.98 | 6.91 | 6.87 | 5.79 | 4.70 | 4.88 |

MAXIMUM DRAFT: 28 Feet or 32 Feet

| | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|
| Iron ore | 6.43 | 6.02 | 5.53 | 5.15 | 4.43 | 3.71 | 3.75 |
| Coal | 2.74 | 2.58 | 2.37 | 2.21 | 1.90 | 1.59 | 1.65 |
| Grain | 11.93 | 11.24 | 10.29 | 9.66 | 8.30 | 6.93 | 7.19 |
| Stone | 2.14 | 2.00 | 1.85 | 1.71 | 1.48 | 1.24 | 1.25 |
| Other bulk | 3.16 | 2.98 | 2.72 | 2.56 | 2.20 | 1.83 | 1.90 |
| General cargo | 6.96 | 6.56 | 6.01 | 5.63 | 4.84 | 4.04 | 4.20 |

## TABLE III-5
## Average Vessel Trip Parameters

| Commodity | Soo | | | Welland | | | St. Lawrence | | |
|---|---|---|---|---|---|---|---|---|---|
| | One-Way Miles | Speed (mph) | Percent Utilization | One-Way Miles | Speed (mph) | Percent Utiliza-tion | One-Way Miles | Speed (mph) | Percent Utiliza-tion |
| Ore | 824 | 14.9 | 50 | 900 | 14.7 | 66 | 900 | 14.9 | 50 |
| Coal | 774 | 14.9 | 71 | 300 | 14.7 | 50 | 300 | 14.9 | 50 |
| Grain | 1,478 | 14.9 | 50 | 1,300 | 14.7 | 50 | 1,300 | 14.9 | 50 |
| Stone | 790 | 14.9 | 50 | 389 | 14.7 | 65 | 389 | 14.9 | 65 |
| Other bulk | 1,149 | 14.9 | 77 | 566 | 14.7 | 72 | 566 | 14.9 | 82 |
| General cargo | 875 | 14.9 | 80 | 900 | 14.7 | 59 | 900 | 14.9 | 59 |

Sources:

- Speed and mileage: documentation of the GL/SLS Lock Capacity Model.
- Utilization equal to:

$$\frac{\text{(tons up)} + \text{(tons down)}}{2 \times \max \text{(tons up, tons down)}}$$, 1978 tonnage. This assumes minimum ballast transits.

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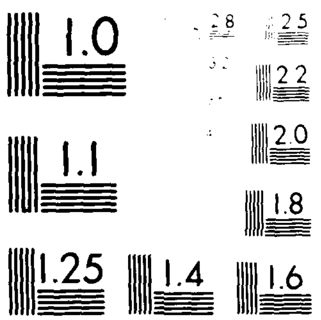



MICROCOPY RESOLUTION TEST CHART

TABLE III-6
Ship Capacity and Immersion Factors

| | Vessel Class 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|
| Draft at capacity | 25'7" | 26'4" | 27'4" | 28'6" | 28' | 28' | 30' |
| Immersion factor (net tons per inch) | 108 | 125 | 136 | 162 | 213 | 246 | 269 |
| Ship carrying capacity (net tons): | | | | | | | |
| . Iron ore and stone | 22,600 | 26,000 | 30,200 | 35,800 | 49,800 | 67,200 | 80,600 |
| . All other | 17,600 | 20,300 | 23,500 | 28,000 | 31,100 | 52,400 | 62,900 |

TABLE III-7
Annual Vessel Costs
($000)

| Vessel Class | Annualized Capital Cost(1) | Annual Operating Cost (1)(2) | Total |
|---|---|---|---|
| 5 | $2,699 | $4,966 | $7,665 |
| 6 | 2,969 | 5,348 | 8,317 |
| 7 | 3,329 | 5,532 | 8,861 |
| 8 | 3,688 | 5,832 | 8,520 |
| 9(3) | 4,723 | 6,658 | 11,381 |
| 10 | 5,758 | 7,483 | 13,241 |
| 11 | 6,657 | 8,096 | 14,753 |

(1) Includes 15 percent profit.

(2) Includes 12 percent overhead.

(3) Interpolated from Classes 8 and 10 since there is only one Class 9 vessel in the fleet and costs are probably not representative.

Source: "Great Lakes Bulk Vessel Operating Costs," U.S. Maritime Administration.

vessel utilization savings in each year are equal to the tons using the system multiplied by the freight rate savings.

Negative productivity changes (i.e., wh n he required freight rate increases) are included in the analysis so the total represents net productivity improvements.

The method for calculating vessel utilization savings for larger lock systems (rather than deeper channels) is shown in Figure III-6. This figure illustrates structural improvement Scenario No. 1, which is construction of 1350 by 115 foot locks. These locks become operational at the Soo Locks in 2018. This postpones reaching capacity until 2050. Between 2018 and 2050 the average vessel class for ore increases from 8.6 to 9.6. In the without-project case, it is assumed that the vessel class will remain at 8.6. The corresponding decrease in required freight rate for ore is from $4.93 per ton to $4.11 per ton. The vessel utilization savings are the tonnage in each year, multiplied by the required freight rate saving in that year, as shown in the figure.

Benefits are calculated for each year and are discounted to net present value as follows:

$$\begin{pmatrix}\text{NPV of}\\ \text{Benefits}\end{pmatrix} = \sum_{T} \frac{B(T)}{(1+r)^{T-T_b}}$$

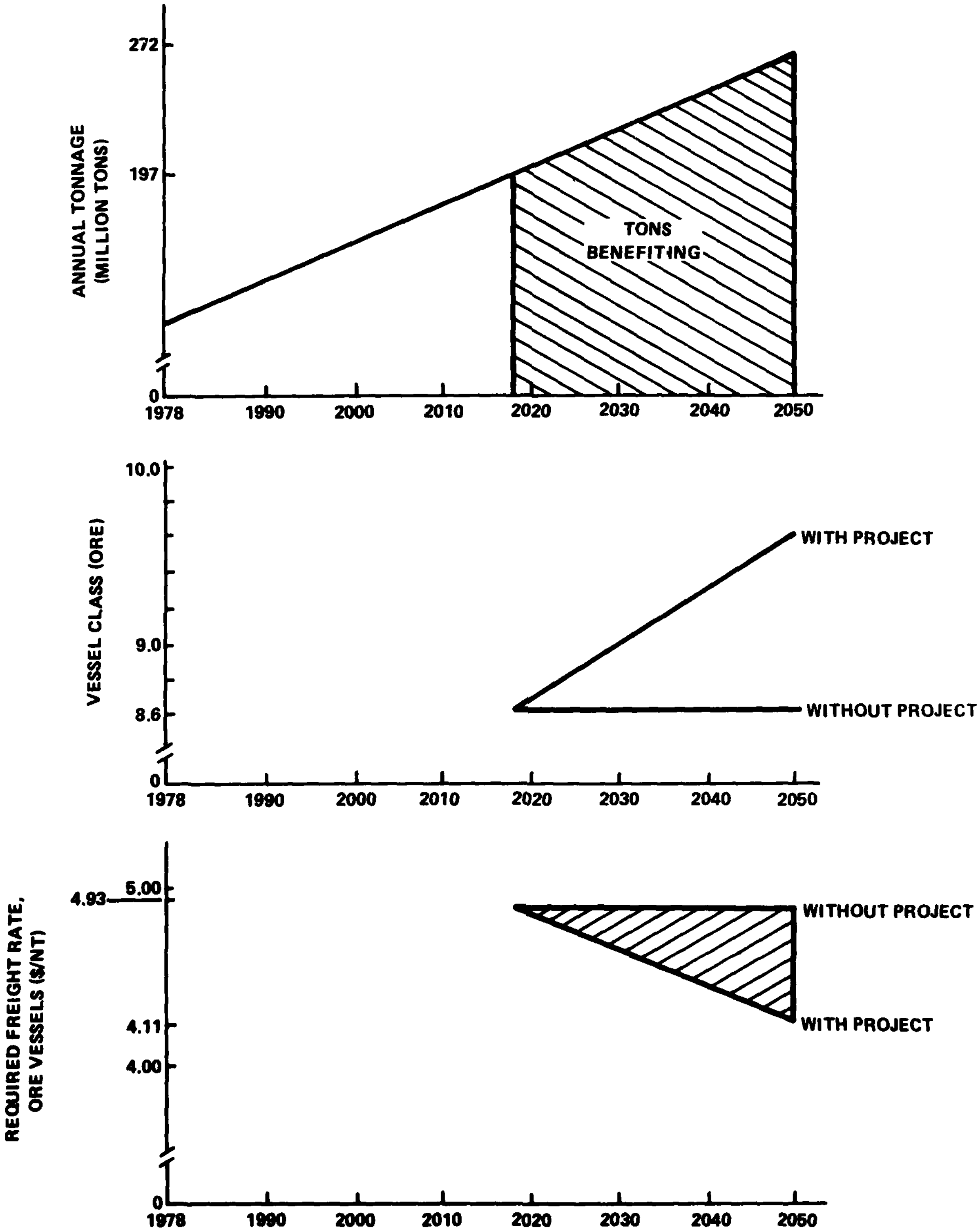
where: $B(T)$ = benefits in year T (sum of rate savings, delay savings and productivity benefits)

$T_b$ = base year for economic analysis (1980 was used)

$r$ = discount factor (7 5/8 percent was used).

In other words, a stream of future benefits ti varies from year to year is converted to an equiva[illegible] et present value. This net present value is converted [illegible]

FIGURE III-6
Vessel Utilization Savings
(Larger Locks)



average annual benefits (a stream of equal annual benefits between 1980 and 2050) as follows:

$$\begin{pmatrix}\text{Average}\\ \text{Annual}\\ \text{Benefits}\end{pmatrix} = \frac{\begin{pmatrix}\text{NPV of}\\ \text{Benefits}\end{pmatrix} \times (r)}{1-\left[(1+r)^{T_b-2050}\right]}$$

Benefits and costs are identified for upper lakes improvements (Soo Locks) and lower lakes improvements (Welland Canal and St. Lawrence Seaway). Some movements, such as export grain shipped from Duluth, involve both lock systems. In these cases benefits were allocated equally to each system for those years after improvements had been made to both lock systems.

2. COSTS

Capital costs and operating and maintenance (O&M) costs were identified for each improvement. Capital costs occur in the year at which capacity would have been reached (project year). These are converted to net present value as follows:

$$NPV\ (C_c) = \frac{C_c}{(1+r)^{T_p - T_b}}$$

where:

$T_p$ = project year
$T_b$ = base year for economic analysis
$C_c$ = capital cost.

Annual O&M costs begin in the project year and are incurred every year until 2050. These are converted to net present value as follows:

$$NPV\ (C_{OM}) = C_{OM} \sum_{n = T_p - T_b}^{n = 2050 - T_b} \frac{1}{(1+r)^n}$$

Average annual costs are given by:

$$\begin{pmatrix}\text{Avg. Annual}\\ \text{Cost}\end{pmatrix} = \frac{\left[NPV\ (C_c) + NPV\ (C_{OM})\right]\ (r)}{1 - (1 + r)^{2050 - T_b}}$$

### 3. BENEFIT-COST RATIO

The benefit-cost ratio is average annual benefits divided by average annual costs. This factor is calculated for the project at each lock system. A combined benefit-cost ratio is also calculated for each scenario (i.e., complementary actions at all three lock systems).

# IV. EVALUATION OF BENEFITS AND COSTS OF ALTERNATIVE SYSTEM IMPROVEMENTS

# IV. EVALUATION OF BENEFITS AND COSTS OF ALTERNATIVE SYSTEM IMPROVEMENTS

This chapter describes a preliminary feasibility analysis of capacity expansion measures. These measures include non-structural and structural improvements. Improvement scenarios were defined which consist of complementary actions taken at each of the three lock systems (Soo, Welland, and St. Lawrence).

Non-structural capacity expansion alternatives are a means of increasing the tonnage processed through a lock system without constructing new locks or performing major structural lock and channel modifications. The non-structural alternatives increase lock capacity by changing a component of the locking system. All of the non-structural alternatives analyzed in this chapter have the effect of reducing locking time. Other non-structural alternatives might increase capacity by, among other things, maximizing the tonnage processed per lockage or by increasing the available lock operating time.

Five non-structural scenarios were evaluated:

- Install traveling kevels
- Increase ship speed into locks
- Decrease chambering time
- Install lock traffic control systems
- All of the above used to maximize utility.

The last of these scenarios combines to the extent possible the first four alternatives to produce the maximum realistic locking time reduction.

Structural alternatives for increasing lock capacity consist of constructing new, larger locks or increasing the depth of existing locks and channels. Five structural scenarios were evaluated. Each structural scenario consists of the use of non-structural alternatives to maximum utility (as described above), combined with different structural improvements. These five scenarios are as follows:

- Operate 1350 by 115 foot locks after the system has reached capacity with the non-structural improvements to maximum utility.

- Operate 1460 by 145 foot locks after the system has reached capacity with the non-structural improvements to maximum utility.

- Allow 28 foot ship draft after the system reaches capacity with the non-structural improvements to maximum utility.

- Allow 32 foot ship draft after system reaches capacity with the non-structural improvements to maximum utility.

- Apply non-structural improvements to all three lock systems, then limit cargo throughout the system based on a capacity condition at the Welland Canal. Operate a 1350 by 115 foot lock at the Soo Locks when it reaches capacity.

Table IV-1 summarizes the results of the benefit-cost analysis. Four cost plans (cost accounting schemes) were used. These plans are as follows:

- Plan A: U.S. costs equal 100 percent of all costs for all lock systems

- Plan B: U.S. costs equal 100 percent of the costs for the Soo Locks and 50 percent of the costs for the Welland Canal and St. Lawrence River

- Plan C: U.S. costs equal 100 percent of the costs for the Soo Locks and costs for the lower lock system as follows:

  - For lock construction or efficiency enhancement: 20 percent (one lock out of five)

  - For channel deepening: 44 percent (corresponding to the system mileage in U.S. territory).

- Plan D: U.S. costs equal to 50 percent of the costs for all locks.

Regardless of cost plan, all improvement scenarios have a benefit-cost ratio greater than one when system benefits and system costs are considered. In terms of benefits and costs, the traffic control system is the most attractive non-structural scenario. For cost Plans A and D, the 28-foot system draft has the highest benefit-cost ratio among systemwide structural scenarios. Construction of 1350 by 115 foot locks has the highest benefit-cost ratio for cost Plans B and C.

TABLE IV-1
Benefit-Cost Summary*
(U.S. Benefits and U.S. Costs)

| Non-Structural | Structural | Benefit-Cost Ratio With Cost Plan A | B | C | D |
|---|---|---|---|---|---|
| Traveling Kevels | - | 25 | 46 | 93 | 50 |
| Increase Ship Speed | - | 73 | 137 | 282 | 145 |
| Reduce Chambering Time | - | 5 | 9 | 20 | 10 |
| Traffic Control | - | 182 | 326 | 652 | 351 |
| N/S to Maximum Utility | 1350' X 115' Locks | 2.2 | 4.2 | 9.6 | 4.3 |
| N/S to Maximum Utility | 1460' X 145' Locks | 1.6 | 2.8 | 4.8 | 3.2 |
| N/S to Maximum Utility | 28-Foot Draft | 2.3 | 3.7 | 4.0 | 4.7 |
| N/S to Maximum Utility | 32-Foot Draft | 1.4 | 1.9 | 2.0 | 2.9 |
| N/S to Maximum Utility | 1350' X 115' Soo Locks* | 10.9 | 18.4 | 31.4 | 21.8 |

* System traffic constrained by capacity condition at the Welland Canal in 1996.

The remaining sections of this chapter describe each of the improvement scenarios in more detail. Each section describes the improvement scenario and summarizes the performance improvement and costs and benefits. The benefit-cost analysis is performed for the upper lock system (Soo Locks) and the lower lock system (Welland Canal and St. Lawrence River).

## 1. NON-STRUCTURAL SCENARIO NO. 1--TRAVELING KEVELS

### (1) Scenario Description

Traveling kevels provide physical assistance to a ship as it moves into a lock instead of having the ship move into the lock entirely under its own power. A ship under its own power must proceed into a lock very slowly to minimize the chance of damaging the lock or the ship. Traveling kevels would enable a ship to move into the lock faster with the same degree of safety. Ship speed entering the lock would increase, decreasing locking time, although some of the gain would be lost in hook-up and release from the assisting devices.

### (2) Performance Improvement

Traveling kevels would reduce the lockage time component of lock entry time which is approximately 15 percent of the total locking time. It is estimated that traveling kevels would reduce entry time by approximately one-half resulting in a total locking time reduction of 7.5 percent.

Capacity at the Soo Locks was extended from 2006 to 2014. At this new capacity level the Soo Locks processed 189,501,000 tons of cargo. This is an increase of 15,762,000 short tons over the 173,739,000 tons that passed through the lock in 2006.

Capacity at the Welland Canal was extended from 1981 to 1985. At capacity in 1985 a total of 80,738,000 tons of cargo was processed through the Welland Canal. This is an increase of 5,540,000 tons over the 75,198,000 tons of cargo processed through the locks in 1981.

Capacity at the St. Lawrence River was extended from 2006 to 2016. The cargo processed through the St. Lawrence Locks at capacity in 2016 was 100,534,000 tons. This is an increase of 8,008,000 tons over the base case capacity in 2006 of 92,526,000 tons.

(3) Benefit-Cost Analysis

Table IV-2 summarizes the benefit-cost analysis. For the Soo Locks, rate savings benefits account for 87 percent of the benefits. Iron ore accounts for 63 percent of the rate savings; the average rate savings is $4.97 per ton. Other bulk accounts for 15 percent of the rate savings, with an average savings of $14.87 per ton. Coal accounts for 13 percent of the rate savings, with an average savings of 13.60 per ton. Delay savings are about 13 percent of the total benefits.

For the lower locks, rate savings also account for 87 percent of the benefits. General cargo accounts for 73 percent of the rate savings (average savings of about $21 per ton) and grain accounts for 13 percent (average savings of $1.60 per ton). Delay savings are about 13 percent of total benefits.

2. NON-STRUCTURAL SCENARIO NO. 2--INCREASE SHIP SPEED

(1) Scenario Description

Using this alternative, a ship would be allowed to enter the lock under its own power at a faster speed. To implement this change, additional safety procedures and devices would be required to reduce the chance of lock damage and ship damage. The ship would have to rely to a greater extent than it does presently on the operation of its own controls, particularly the application and reversal of power. This would reduce margins for safety; therefore, additional safety measures would be required to prevent ship and lock damage. Additional safety devices may include replaceable fenders, energy absorbers, and rolling fenders. Some of these devices are currently in place at the Soo Locks and at the St. Lawrence River Locks.

(2) Performance Improvement

Increasing the ship speed into the lock would increase the lock capacity by reducing the lock entry time component of the locking time. Lock entry time is approximately 15 percent of the total locking time. Increasing the ship speed into the lock would reduce lock entry time approximately 20 percent at the Soo and St. Lawrence River, and approximately 33 percent at the Welland Canal. Total locking time would correspondingly be reduced 2.5 percent at the

TABLE IV-2
Traveling Kevels

| Lock System | Improvement | Average Annual U.S. Benefits ($ Million) Rate Savings | Delay Ben. | Total |
|---|---|---|---|---|
| Upper | Traveling Kevels | 9.77 | 1.41 | 11.18 |
| Lower | Traveling Kevels | 51.95 | 7.83 | 59.78 |

| Lock System | Cost Plan | Average Annual ($ Million) U.S. Benefit | U.S. Cost | Benefit-Cost Ratio |
|---|---|---|---|---|
| Upper | A | 11.18 | 0.25 | 45 |
| | B | 11.18 | 0.25 | 45 |
| | C | 11.18 | 0.25 | 45 |
| | D | 11.18 | 0.13 | 86 |
| Lower | A | 59.78 | 2.56 | 23.4 |
| | B | 59.78 | 1.28 | 46.7 |
| | C | 59.78 | 0.51 | 117.2 |
| | D | 59.78 | 1.28 | 46.7 |
| Total | A | 70.96 | 2.81 | 25.3 |
| | B | 70.96 | 1.53 | 46.4 |
| | C | 70.96 | 0.76 | 93.4 |
| | D | 70.96 | 1.41 | 50.3 |

Soo and St. Lawrence River, and 5 percent at the Welland Canal. The improvement will reduce locking times to a greater extent at the Welland Canal than at the Soo and St. Lawrence River Locks because ships already enter the Soo and St. Lawrence River Locks, which have some safety bumpers and fenders, at higher speeds. Locking time reductions are likely to vary widely between individual ships.

Capacity at the Soo Locks was extended from 2006 to 2008. At capacity in 2008 the amount of cargo processed through the Soo Locks was 177,988,000 tons. This is an increase of 4,249,000 tons over the 173,739,000 tons processed through the lock in 2006.

Capacity at the Welland Canal was extended from 1981 to 1984. At capacity in 1984 a total of 78,921,000 tons of cargo was processed through the Welland Canal. This is an increase of 3,723,000 tons over the 75,198,000 tons of cargo processed through the locks in 1981.

Capacity at the St. Lawrence River was extended from 2006 to 2010. The amount of cargo passing through the St. Lawrence River Locks at capacity in 2010 was 96,198,000 tons. This is an increase of 3,672,000 tons over the 92,526,000 tons processed through the locks in 2006.

(3) <u>Benefit-Cost Analysis</u>

Table IV-3 summarizes the benefit-cost analysis. For the Soo Locks, rate savings benefits account for 88 percent of the benefits. Iron ore accounts for 59 percent of the rate savings; the average rate savings is $4.93 per ton. Other bulk accounts for 13 percent of the rate savings, with an average savings of $14.88 per ton. Coal accounts for 19 percent of the rate savings, with an average savings of $12.29 per ton. Delay savings are about 12 percent of the total benefits.

For the lower locks, rate savings account for 89 percent of the benefits. General cargo accounts for 78 percent of the rate savings (average savings of about $21 per ton) and grain accounts for 11 percent (average savings of $3.52 per ton). Delay savings are about 11 percent of total benefits.

TABLE IV-3
Increase Ship Speed

| Lock System | Improvement | Average Annual U.S. Benefits ($ Million) Rate Savings | Delay Ben. | Total |
|---|---|---|---|---|
| Upper | Increase Ship Speed | 3.20 | 0.43 | 3.63 |
| Lower | Increase Ship Speed | 44.48 | 5.48 | 49.96 |

| Lock System | Cost Plan | Average Annual ($ Million) U.S. Benefit | U.S. Cost | Benefit-Cost Ratio |
|---|---|---|---|---|
| Upper | A | 3.63 | 0.05 | 73 |
| | B | 3.63 | 0.05 | 73 |
| | C | 3.63 | 0.05 | 73 |
| | D | 3.63 | 0.03 | 145 |
| Lower | A | 49.96 | 0.68 | 73 |
| | B | 49.96 | 0.34 | 147 |
| | C | 49.96 | 0.14 | 357 |
| | D | 49.96 | 0.34 | 147 |
| Total | A | 53.59 | 0.73 | 73 |
| | B | 53.59 | 0.39 | 137 |
| | C | 53.59 | 0.19 | 282 |
| | D | 53.59 | 0.37 | 145 |

## 3. NON-STRUCTURAL SCENARIO NO. 3--DECREASE LOCK CHAMBERING TIME

### (1) Scenario Description

The time taken to raise or lower a ship in a lock would be decreased by increasing the filling/dumping rate of the lock. The exit times of downbound ships would be reduced by providing downstream longitudinal hydraulic assistance. The combination of these measures would reduce locking time by reducing the lock chambering time. Reducing the filling/dumping time of the lock would directly reduce the lock cycle time, increasing lock capacity. Lock filling/dumping times would be reduced by increasing culvert sizes and reducing valve operating times. Longitudinal hydraulic assistance might be given to ships exiting downstream by opening the exit gates before the water level is completely down.

### (2) Performance Improvement

Chambering time is approximately 15 percent of the total locking time at the Welland Canal Lock, and approximately 10 percent of the total locking time at the Soo and St. Lawrence River Locks. By expanding the hydraulics of the locks, chambering could conceivably be reduced 10 percent at the Soo and St. Lawrence River and 15 percent at the Welland Canal. The corresponding reduction in total locking time would be 1 percent at the Soo and St. Lawrence River Locks and 2.5 percent at the Welland Locks. Downstream longitudinal hydraulic assistance could be expected to reduce the downstream locking time an additional 4.5 percent at the Soo and St. Lawrence River Locks and 2.5 percent at the Welland Canal. Chambering times can be improved more at the Welland Canal Locks which have smaller capacity dump/fill culverts than the Soo and St. Lawrence River Locks. Downstream longitudinal hydraulic assistance will reduce exit times more at the Soo and St. Lawrence River Locks, where it is not in use at the constraining lock, than at the Welland Locks where it is already used to some extent.

Capacity at the Soo Locks was extended from 2006 to 2010. At capacity in 2010, the amount of cargo processed through the Soo Locks was 182,250,000 tons. This is an increase of 8,511,000 tons over the 173,739,000 tons processed through the lock in 2006.

Capacity at the Welland Canal was extended from 1981 to 1983. At capacity in 1983, a total of 78,839,000 tons of cargo was processed through the Welland Canal. This is an increase of 3,641,000 tons over the 75,198,000 tons of cargo processed through the locks in 1981.

Capacity at the St. Lawrence River was extended from 2006 to 2010. The amount of cargo passing through the St. Lawrence River Locks at capacity in 2010 was 96,353,000 tons. This is an increase of 3,827,000 tons over the 92,526,000 tons processed through the locks in 2006.

(3) Benefit-Cost Analysis

Table IV-4 summarizes the benefit-cost analysis. For the Soo Locks, rate savings benefits account for 88 percent of the benefits. Iron ore accounts for 61 percent of the rate savings; the average rate savings is $4.93 per ton. Other bulk accounts for 14 percent of the rate savings, with an average savings of $14.88 per ton. Coal accounts for 16 percent of the rate savings, with an average savings of $12.29 per ton. Delay savings are about 12 percent of the total benefits.

For the lower locks, rate savings account for 89 percent of the benefits. General cargo accounts for 81 percent of the rate savings (average savings of about $21 per ton) and grain accounts for 8 percent (average savings of $3.52 per ton). Delay savings are about 11 percent of total benefits.

## 4. NON-STRUCTURAL SCENARIO NO. 4--TRAFFIC CONTROL SYSTEMS AT LOCKS

(1) Scenario Description

A traffic control system would organize the flow of ships as they approach a lock. Currently, high-frequency voice radio is used to control ships approaching the Soo Locks. The Welland Canal presently has a manual traffic control system for ships that are in the canal. The proposed traffic control system would be designed to reduce delays in lock approaches and would allow faster responses by the lock operators in the locking operation.

TABLE IV-4
Reduce Chamber Time

| Lock System | Improvement | Average Annual U.S. Benefits ($ Million) Rate Savings | Delay Ben. | Total |
|---|---|---|---|---|
| Upper | Reduce Chamber Time | 5.75 | 0.81 | 6.56 |
| Lower | Reduce Chamber Time | 34.26 | 4.11 | 38.37 |

| | | Average Annual ($ Million) | | |
|---|---|---|---|---|
| Lock System | Cost Plan | U.S. Benefit | U.S. Cost | Benefit-Cost Ratio |
| Upper | A | 6.56 | .54 | 12.1 |
| | B | 6.56 | .54 | 12.1 |
| | C | 6.56 | .54 | 12.1 |
| | D | 6.56 | .27 | 24.2 |
| Lower | A | 38.37 | 8.82 | 4.4 |
| | B | 38.37 | 4.41 | 8.7 |
| | C | 38.37 | 1.76 | 21.8 |
| | D | 38.37 | 4.41 | 8.7 |
| Total | A | 44.93 | 9.36 | 4.8 |
| | B | 44.93 | 4.95 | 9.1 |
| | C | 44.93 | 2.30 | 19.5 |
| | D | 44.93 | 4.68 | 9.6 |

(2) Performance Improvement

Approach time is approximately 20 percent of the total locking time at the Soo and St. Lawrence River Locks, and 25 percent of the total at the Welland Canal Locks. The proposed traffic control system would have the potential to reduce approach times approximately 22 percent at the Soo and St. Lawrence River, and approximately 12 percent at the Welland Canal. It is estimated that total locking times would correspondingly be reduced 4.5 percent at the Soo and St. Lawrence River Locks, and 3.0 percent at the Welland Locks. The proposed control system would reduce locking times more at the Soo and St. Lawrence River because the present means of traffic control at these locks is less sophisticated than that in use at the Welland Canal. It is judged, however, that the system in use at the Welland also has the potential for some improvement.

Capacity at the Soo Locks was extended from 2006 to 2010. At capacity in 2010, the amount of cargo processed through the Soo Locks was 182,250,000 tons. This is an increase of 8,511,00 tons over the 173,739,000 tons processed through the lock in 2006.

Capacity at the Welland Canal was extended from 1981 to 1983. At capacity in 1983, a total of 78,735,000 tons of cargo was processed through the Welland Canal. This is an increase of 3,536,000 tons over the 75,198,000 tons of cargo processed through the locks in 1981.

Capacity at the St. Lawrence River was extended from 2006 to 2012. The amount of cargo passing through the St. Lawrence River Locks at capacity in 2012 was 97,789,000 tons. This is an increase of 5,263,000 tons over the 92,526,000 tons processed through the locks in 2006.

(3) Benefit-Cost Analysis

Table IV-5 summarizes the benefit-cost analysis. For the Soo Locks, rate savings benefits account for 88 percent of the benefits. Iron ore accounts for 61 percent of the rate savings; the average rate savings is $4.93 per ton. Other bulk accounts for 14 percent

TABLE IV-5
Traffic Control Systems

| Lock System | Improvement | Average Annual U.S. Benefits ($ Million) Rate Savings | Delay Ben. | Total |
|---|---|---|---|---|
| Upper | Traffic Control | 5.75 | 0.81 | 6.56 |
| Lower | Traffic Control | 34.54 | 4.52 | 39.06 |

| Lock System | Cost Plan | Average Annual ($ Million) U.S. Benefit | U.S. Cost | Benefit-Cost Ratio |
|---|---|---|---|---|
| Upper | A | 6.56 | 0.03 | 219 |
| | B | 6.56 | 0.03 | 219 |
| | C | 6.56 | 0.03 | 219 |
| | D | 6.56 | 0.02 | 437 |
| Lower | A | 39.06 | .22 | 177 |
| | B | 39.06 | .11 | 355 |
| | C | 39.06 | .04 | 976 |
| | D | 39.06 | .11 | 355 |
| Total | A | 45.62 | .25 | 182 |
| | B | 45.62 | .14 | 326 |
| | C | 45.62 | .07 | 652 |
| | D | 45.62 | .13 | 351 |

of the rate savings, with an average savings of $14.88 per ton. Coal accounts for 16 percent of the rate savings, with an average savings of $12.29 per ton. Delay savings are about 12 percent of the total benefits.

For the lower locks, rate savings also account for 88 percent of the benefits. General cargo accounts for 80 percent of the rate savings (average savings of about $21 per ton) and grain accounts for 9 percent (average savings of $3.52 per ton). Delay savings are about 12 percent of total benefits.

## 5. NON-STRUCTURAL ALTERNATIVES TO MAXIMUM UTILITY

This term refers to the combination of the preceding non-structural alternatives in order to provide the greatest possible increase in lock system capability. Traveling kevels provide the largest capacity increase of all the individual non-structural alternatives and therefore were included in the non-structural improvements to maximum utility. Since the ship entering and exiting the lock will be under the control of the traveling kevels, the alternatives of increasing ship speed into the lock and the downstream longitudinal hydraulic assistance are excluded as independent contributions toward the reduction of lockage time. The capacity gain from traveling kevels is greater than the gain for the combination of the alternatives of increasing ship speed and downstream longitudinal hydraulic assistance.

The three non-structural improvements of traveling kevels, reducing dump/fill times and traffic control systems are independent, and may therefore all be implemented together. Since each reduces a different component of the locking time, their locking time improvements are additive. The three improvements combined, therefore, were selected as the non-structural alternatives implemented to maximum utility.

### (1) Performance Improvement

At the Soo Locks, traveling kevels reduce locking time 7.5 percent, decreased dump/fill time reduces locking time 1.0 percent, and the traffic control system reduces locking time 4.5 percent. Implemented together, these alternatives reduce locking times at the Soo Locks by 13 percent.

Capacity at the Soo Locks was extended from 2006 to 2018. At capacity in 2018, the amount of cargo processed through the Soo Locks was 196,766,000 tons. This is an increase of 23,072,000 tons over the 173,739,000 tons processed through the lock in 2006.

At the Welland Canal, traveling kevels reduce locking time 7.5 percent, decreased dump/fill time decreases locking time 2.5 percent, and the traffic control system reduces locking time 3.0 percent. Implemented together, these alternatives reduce locking times at the Welland Canal by 13 percent.

Capacity at the Welland Canal was extended from 1981 to 1996. At capacity in 1996, a total of 88,598,000 tons of cargo was processed through the Welland Canal. This is an increase of 13,400,000 tons over the 75,198,000 tons of cargo processed through the locks in 1981.

At the St. Lawrence River Locks, traveling kevels reduce locking time 7.5 percent, decreased dump/fill time reduces locking time 1.0 percent, and the traffic control system reduces locking time 4.5 percent. Implemented together, these alternatives reduce locking times at the St. Lawrence River Locks by 13 percent.

Capacity at the St. Lawrence River was extended from 2006 to 2024. The amount of cargo passing through the St. Lawrence River Locks at capacity in 2024 was 108,597,000 tons. This is an increase of 16,071,000 tons over the 92,526,000 tons processed through the locks in 2006.

(2) Benefit-Cost Analysis

The use of non-structural alternatives to maximum utility was combined with various structural improvements to produce integrated structural improvement scenarios. The costs and benefits of these combined alternatives are discussed in the following sections.

## 6. STRUCTURAL SCENARIO NO. 1--1350 BY 115 FOOT LOCKS

(1) Scenario Description

After reaching capacity with non-structural alternatives implemented to maximum utility, 1350 by 115 foot locks were placed in operation. These locks are capable of handling ships 1100 by 105 feet, which are considered to be Class 11. No increase in system draft from 25.5 feet was made.

At the Soo Locks, which reached capacity with non-structural alternatives implemented to maximum utility in 2018, a single 1350 by 115 foot lock was constructed. This lock was built in place of the Davis Lock. The existing Sabin, MacArthur, and Poe Locks were not changed. The non-structural improvements were also implemented on this new lock.

At the Welland Canal, which reached capacity with non-structural alternatives implemented to maximum utility in 1996, the existing eight lock system was abandoned and a new lock system consisting of four 1350 by 115 foot locks was built in its place. The non-structural improvements retrofitted on the existing locks were assumed to be built into the new locks.

In order to take advantage of the structural improvement made at the Welland Canal in 1996, both non-structural and structural improvements were implemented at the St. Lawrence River in 1996. The existing seven lock system was abandoned and a new lock system consisting of five 1350 by 115 foot locks was built. In the new St. Lawrence River Lock system, the Snell and Eisenhower Locks were combined into a single lock as were the Upper and Lower Beauharnois. The non-structural improvements, retrofitted on the existing locks, were assumed to be built into the new locks.

Since the St. Lawrence River would not have reached capacity until 2006, benefits were not claimed until that time.

(2) Performance Improvement

Capacity at the Soo Locks was extended to 2050. At capacity in 2050, a total of 272,245,000 tons of cargo used the locks, an increase of 75,479,000 tons over the amount passing through the locks in 2018 when the system was at capacity with the non-structural alternatives combined to maximum utility.

Capacity at the Welland Canal was extended to 2034. At capacity in 2034, 128,693,000 tons of cargo passed through the locks. This tonnage is an increase of 40,095,000 tons over the capacity tonnage of 88,598,000 tons processed through the existing Welland Canal in 1996 when capacity was reached with non-structural alternatives implemented to maximum utility.

At the St. Lawrence River, capacity was extended until 2048. At capacity in 2048, a total of 144,539,000 tons of cargo was passed through the new St. Lawrence River Locks. This total is an increase of 35,942,000 tons over the 108,597,000 tons which would have been the capacity limit at the St. Lawrence River with non-structural alternatives combined to maximum utility.

(3) Benefit-Cost Analysis

Table IV-6 summarizes the benefit-cost analysis. For the upper locks, rate savings are the largest benefit category, accounting for 74 percent of the benefits. Iron ore accounts for 64 percent of the rate savings; the average rate savings is $4.93 per ton. Other bulk accounts for 17 percent of the rate savings, with an average savings of $14.88 per ton. Coal accounts for 11 percent of the rate savings, with an average savings of $12.29 per ton. Delay savings are 12 percent of the benefits, and vessel utilization savings are 10 percent. Most of the vessel utilization savings are due to the use of larger ships for iron ore.

For the lower locks, rate savings account for 81 percent of the benefits. General cargo accounts for 47 percent of the rate savings (average savings of about $21 per ton) and grain accounts for 26 percent (average savings of $3.52 per ton). Delay savings are 18 percent of the benefits. Vessel utilization savings are almost negligible.

Depending on the cost sharing assumption used, the benefit-cost ratio for the upper system is always greater than 11. At the lower system the benefit-cost ratio varies between 1.9 and 9.3. The benefit-cost ratio for the entire scenario varies between 2.2 and 9.6.

## 7. STRUCTURAL SCENARIO NO. 2--1460 BY 145 FOOT LOCKS

(1) Scenario Description

New locks were placed in operation at each lock system after capacity was reached with non-structural alternatives implemented to maximum utility. In this case the new locks were 1460 by 145 feet, capable of handling 1200 by 130 foot ships (Class 12). No change in the system draft from 25.5 feet was made.

TABLE IV-6
1350 by 115 Foot Locks

| Lock System | Improvement | Average Annual U.S. Benefits ($ Million): Rate Savings | Delay Ben. | Vessel Util. Savings | Total |
|---|---|---|---|---|---|
| Upper | NS to Max Utility | 12.69 | 1.86 | - | 14.55 |
| | 1350 X 115 Locks | 7.10 | 1.24 | 2.55 | 10.89 |
| | | 19.79 | 3.10 | 2.55 | 25.44 |
| Lower | NS to Max Utility | 82.99 | 18.00 | - | 100.99 |
| | 1350 X 115 Locks | 23.12 | 6.29 | 0.95 | 30.36 |
| | | 106.11 | 24.29 | 0.95 | 131.35 |

| Lock System | Cost Plan | Average Annual ($ Million): U.S. Benefits | U.S. Cost | Benefit-Cost Ratio |
|---|---|---|---|---|
| Upper | A | 25.44 | 2.31 | 11.0 |
| | B | 25.44 | 2.31 | 11.0 |
| | C | 25.44 | 2.31 | 11.0 |
| | D | 25.44 | 1.16 | 21.9 |
| Lower | A | 131.35 | 70.25 | 1.9 |
| | B | 131.35 | 35.13 | 3.7 |
| | C | 131.35 | 14.05 | 9.3 |
| | D | 131.35 | 35.13 | 3.7 |
| Total | A | 156.79 | 72.56 | 2.2 |
| | B | 156.79 | 37.44 | 4.2 |
| | C | 156.79 | 16.36 | 9.6 |
| | D | 156.79 | 36.29 | 4.3 |

At the Soo Locks, which reached capacity in 2018 with non-structural alternatives combined to maximum utility, one new 1460 by 145 foot lock was constructed. This new lock was constructed in place of the Sabin and Davis Locks. The Soo Lock System then consisted of the MacArthur and Poe Locks, which were not changed, and the new Sabin-Davis Lock. The non-structural alternatives already in use at the MacArthur and Poe Locks were implemented at the new Sabin-Davis.

At the Welland Canal, which reached capacity in 1996 with non-structural alternatives combined to maximum utility, four new 1460 by 145 foot locks were constructed. These new locks replaced the existing eight locks. The non-structural alternatives that were in use on the existing Welland Canal Locks were assumed to be built into the new locks.

In order to take advantage of the structural improvement at the Welland Canal in 1996, both structural and non-structural improvements were made at the St. Lawrence River in 1996. The existing seven locks were abandoned and a new series of five 1460 by 145 foot locks were built. Construction of the new lock system was optimized by combining the Snell and Eisenhower Locks into one lock, and the Upper and Lower Beauharnois Locks into one lock. The non-structural improvements were built into the five new locks.

Since the St. Lawrence River Locks would not have reached capacity until 2006, benefits were not claimed until that time.

(2) Performance Improvement

Capacity at the Soo Locks was extended to beyond 2050. The 2050 unconstrained cargo forecast is 272,247,000 tons. This is an increase of 75,481,000 tons over the 196,776,000 tons of cargo that passed through the Soo Locks at capacity with non-structural alternatives implemented to maximum utility in 2018.

Capacity at the Welland Canal was extended to 2046. At capacity in 2046, cargo flow will equal 148,229,000 tons. Capacity of the Welland Canal increased by 59,631,000 tons over the 88,598,000 tons passed through the locks at capacity in 1996 with non-structural alternatives combined to maximum utility.

At the St. Lawrence River, the 2050 unconstrained cargo forecast may be passed without a capacity condition occurring. The 2050 unconstrained cargo forecast is 148,259,000 tons. This is an increase of 39,662,000 tons over the capacity limit of 108,597,000 tons after implementation of non-structural alternatives to maximum utility.

(3) Benefit-Cost Analysis

Table IV-7 summarizes the benefit-cost analysis. For the upper locks, rate savings are the largest benefit category, accounting for 74 percent of the benefits. Iron ore accounts for 64 percent of the rate savings; the average rate savings is $4.93 per ton in 2018. Other bulk accounts for 17 percent of the rate savings, with an average savings of $14.88 per ton. Coal accounts for 11 percent of the rate savings, with an average savings of $12.29 per ton. Delay savings are 12 percent of the benefits, and vessel utilization savings are 10 percent. Most of the vessel utilization savings are due to the use of larger ships for iron ore.

For the lower locks, rate savings account for 81 percent of the benefits. General cargo accounts for 47 percent of the rate savings (average savings of about $21 per ton in 2018) and grain accounts for 26 percent (average savings of $3.52 per ton in 2018). Delay savings are 18 percent of the benefits. Vessel utilization savings are almost negligible.

Depending on the cost sharing assumption used, the benefit-cost ratio for the upper system is either 1.6 or 3.2. At the lower system the benefit-cost ratio varies between 1.6 and 8.1. The benefit-cost ratio for the entire scenario varies between 1.6 and 4.8.

## 8. STRUCTURAL SCENARIO NO. 3--28 FOOT SHIP DRAFT

(1) Scenario Description

At each lock system capacity was increased by increasing the allowable ship draft to 28 feet after capacity was reached with non-structural alternatives combined to maximum utility. Drafts were not increased at the Sabin and Davis Locks. No other change was made to the size of the locks. The maximum size ships were Class 10 at the Soo and Class 7 at the Welland and St. Lawrence River. Increasing ship draft

TABLE IV-7
1460 by 145 Foot Locks

| Lock System | Improvement | Average Annual U.S. Benefits ($ Million) Rate Savings | Delay Ben. | Vessel Util. Savings | Total |
|---|---|---|---|---|---|
| Upper | N/S to Max Utility | 12.69 | 1.86 | - | 14.55 |
| | 1460 X 145 Locks | 7.10 | 1.24 | 3.97 | 12.31 |
| | | 19.79 | 3.10 | 3.97 | 26.86 |
| Lower | N/S to Max Utility | 82.99 | 18.00 | - | 101.04 |
| | 1460 X 145 Locks | 24.25 | 6.53 | 1.02 | 31.80 |
| | | 107.24 | 24.53 | 1.02 | 132.84 |

| Lock System | Cost Plan | Average Annual ($ Million) U.S. Benefit | U.S. Cost | Benefit-Cost Ratio |
|---|---|---|---|---|
| Upper | A | 26.86 | 16.57 | 1.6 |
| | B | 26.86 | 16.57 | 1.6 |
| | C | 26.86 | 16.57 | 1.6 |
| | D | 26.86 | 8.29 | 3.2 |
| Lower | A | 132.84 | 82.17 | 1.6 |
| | B | 132.84 | 41.09 | 3.2 |
| | C | 132.84 | 16.43 | 8.1 |
| | D | 132.84 | 41.09 | 3.2 |
| Total | A | 159.70 | 98.74 | 1.6 |
| | B | 159.70 | 57.66 | 2.8 |
| | C | 159.70 | 33.00 | 4.8 |
| | D | 159.70 | 49.38 | 3.2 |

augments the capacity of a lock system by increasing the cargo carrying capacity of each ship, provided that each ship has a sufficient molded depth to allow it to operate at the increased draft.

(2) Performance Improvement

Capacity at the Soo Locks was extended to 2026. At capacity in 2026, a total of 213,734,000 tons used the locks, an increase of 16,968,000 tons over the capacity tonnage of 196,766,000 tons with non-structural alternatives combined to maximum utility in 2018.

Capacity at the Welland Canal was extended to 2012. At capacity in 2012, cargo flow will be 102,558,000 tons. This is an increase of 13,960,000 tons over the 88,598,000 tons of cargo passed at capacity with the non-structural alternatives to maximum utility in 1996.

At the St. Lawrence River, structural and non-structural improvements were implemented in 1996, when structural improvements were implemented at the Welland Canal. This extended capacity to 2034, allowing 122,945,000 tons through the locks. This is an increase of 14,348,000 tons over what would have been the capacity limit of 108,597,000 tons with non-structural alternatives used to maximum utility. Benefits were not claimed until after 2006, when the St. Lawrence would have reached capacity with no improvements.

(3) Benefit-Cost Analysis

Table IV-8 summarizes the benefit-cost analysis. For the upper locks, rate savings are the largest benefit category, accounting for 67 percent of the benefits. Iron ore accounts for 64 percent of the rate savings; the average rate savings is $4.93 per ton. Other bulk accounts for 16 percent of the rate savings, with an average savings of $14.88 per ton. Coal accounts for 11 percent of the rate savings, with an average savings of $12.29 per ton. Delay savings are 10 percent of the benefits, and vessel utilization savings are 23 percent. The latter savings are due to carrying more tonnage per trip. Iron ore accounts for 73 percent of the vessel utilization savings, and coal about 20 percent.

TABLE IV-8
28 Foot Draft

| Lock System | Improvement | Average Annual U.S. Benefits ($ Million) Rate Savings | Delay Ben. | Vessel Util. Savings | Total |
|---|---|---|---|---|---|
| Upper | N/S to Max Utility | 12.69 | 1.86 | - | 14.55 |
| | 28 Foot Draft | 3.84 | 0.61 | 5.77 | 10.22 |
| | | 16.53 | 2.47 | 5.77 | 24.77 |
| Lower | N/S to Max Utility | 82.99 | 18.00 | - | 101.04 |
| | 28 Foot Draft | 16.51 | 4.55 | 3.85 | 24.91 |
| | | 99.50 | 22.55 | 3.85 | 125.95 |

| Lock System | Cost Plan | Average Annual ($ Million) U.S. Benefit | U.S. Cost | Benefit-Cost Ratio |
|---|---|---|---|---|
| Upper | A | 24.77 | 16.13 | 1.5 |
| | B | 24.77 | 16.13 | 1.5 |
| | C | 24.77 | 16.13 | 1.5 |
| | D | 24.77 | 8.07 | 3.1 |
| Lower | A | 125.95 | 48.50 | 2.6 |
| | B | 125.95 | 24.25 | 5.2 |
| | C | 125.95 | 21.34 | 5.9 |
| | D | 125.95 | 24.25 | 5.2 |
| Total | A | 150.72 | 64.63 | 2.3 |
| | B | 150.72 | 40.38 | 3.7 |
| | C | 150.72 | 37.47 | 4.0 |
| | D | 150.72 | 32.32 | 4.7 |

For the lower locks, rate savings account for 79 percent of the benefits. General cargo accounts for 46 percent of the rate savings (average savings of about $21 per ton) and grain accounts for 27 percent (average savings of $3.52 per ton). Delay savings are 18 percent of the benefits. Vessel utilization savings are only 3 percent of the benefits.

Depending on the cost sharing assumption used, the benefit-cost ratio for the upper system is either 1.5 or 3.1. At the lower system, the benefit-cost ratio varies between 2.6 and 5.9. The benefit-cost ratio for the entire scenario varies between 2.3 and 4.7.

## 9. STRUCTURAL SCENARIO NO. 4--32 FOOT SHIP DRAFT

### (1) Scenario Description

At each lock system, as capacity was reached with non-structural alternatives combined to maximum utility, the capacity of the lock system was increased by increasing allowable ship draft to 32 feet. Drafts were not increased at the Sabin or Davis Locks because they mainly handle ballasted ships. No other change was made in the size of the locks. Maximum vessel class was still Class 10 at the Soo Locks and Class 7 at the Welland and St. Lawrence River Locks.

Increasing ship draft augments lock capacity by increasing the carrying capacity of each ship, provided that each ship has sufficient molded depth to operate at deeper drafts.

### (2) Performance Improvement

Capacity at the Soo Locks was extended to 2038. The amount of cargo passed through the Soo at capacity in 2038 was 241,652,000 tons. This was an increase of 44,886,000 tons over the 196,766,000 tons of cargo passed through the Soo in 2018 when capacity was reached with non-structural alternatives implemented to maximum utilization.

Capacity at the Welland Canal was extended to 2030. The tonnage passed through the Welland Canal in 2030 was 122,586,000 tons. This is an increase of 33,988,000 tons over the capacity limit achieved with implementation of non-structural alternatives to maximum utility.

At the St. Lawrence River, non-structural improvements and channel and lock deepening were implemented in 1996, when structural improvements were implemented at the Welland Canal. This extended capacity to 2046, allowing 141,885,000 tons through the locks. This is an increase of 33,288,000 tons over the capacity limit achieved with implementation of non-structural alternatives to maximum utility.

Since the St. Lawrence River would not have reached capacity until 2006 with no improvements, benefits were not claimed until that time.

(3) Benefit-Cost Analysis

Table IV-9 summarizes the benefit-cost analysis. For the upper locks, rate savings are the largest benefit category, accounting for 67 percent of the benefits. Iron ore accounts for 68 percent of the rate savings; the average rate savings is $4.93 per ton. Other bulk accounts for 17 percent of the rate savings, with an average savings of $14.88 per ton. Coal accounts for 11 percent of the rate savings, with an average savings of $12.29 per ton. Delay savings are 10 percent of the benefits, and vessel utilization savings are 22 percent. The latter savings are due to carrying more tonnage per trip. Iron ore accounts for 74 percent of the vessel utilization savings, and coal about 20 percent.

For the lower locks, rate savings account for 79 percent of the benefits. General cargo accounts for 46 percent of the rate savings (average savings of about $21 per ton) and grain accounts for 27 percent (average savings of $3.52 per ton). Delay savings are 18 percent of the benefits. Vessel utilization savings are only 3 percent of the benefits.

Depending on the cost sharing assumption used, the benefit-cost ratio for the upper system is either 0.5 or 1.1. At the lower system the benefit-cost ratio varies between 2.3 and 5.2. The benefit-cost ratio for the entire scenario varies between 1.4 and 2.9.

## 10. STRUCTURAL SCENARIO NO. 5--CONSTRAINED CARGO FLOWS, 1350 BY 115 FOOT LOCK AT SOO LOCKS

(1) Scenario Description

In this scenario the only improvements to the lower lock system are non-structural. With non-structural improvements combined to maximum utility,

TABLE IV-9
32 Foot Draft

| Lock System | Improvement | Average Annual U.S. Benefits ($ Million) Rate Savings | Delay Ben. | Vessel Util. Savings | Total |
|---|---|---|---|---|---|
| Upper | N/S to Max Utility | 12.69 | 1.86 | - | 14.55 |
| | 32 Foot Draft | 6.46 | 1.06 | 6.08 | 13.60 |
| | | 19.15 | 2.92 | 6.08 | 28.15 |
| Lower | N/S to Max Utility | 82.99 | 18.00 | - | 101.04 |
| | 32 Foot Draft | 22.26 | 6.15 | 3.88 | 32.29 |
| | | 105.25 | 24.15 | 3.88 | 133.33 |

| Lock System | Cost Plan | Average Annual ($ Million) U.S. Benefit | U.S. Cost | Benefit-Cost Ratio |
|---|---|---|---|---|
| Upper | A | 28.77 | 54.33 | 0.5 |
| | B | 28.77 | 54.33 | 0.5 |
| | C | 28.77 | 54.33 | 0.5 |
| | D | 28.77 | 27.17 | 1.1 |
| Lower | A | 133.33 | 58.09 | 2.3 |
| | B | 133.33 | 29.05 | 4.6 |
| | C | 133.33 | 25.56 | 5.2 |
| | D | 133.33 | 29.05 | 4.6 |
| Total | A | 162.10 | 112.42 | 1.4 |
| | B | 162.10 | 83.38 | 1.9 |
| | C | 162.10 | 79.89 | 2.0 |
| | D | 162.10 | 56.22 | 2.9 |

the Welland Canal reached capacity in 1996. No alterna- tives were implemented at the Welland Canal past 1996 to relieve this capacity condition. Instead, the Welland Canal was allowed to constrain the cargo flow through the GL/SLS System. Non-structural alternatives were implemented at the Soo and St. Lawrence River Locks when they reached capacity. A 1350 by 115 foot lock was placed in operation at the Soo when capacity was reached there with non-structural alternatives combined to maximum utility.

The new lock at the Soo was built as in structural Scenario No. 1. The Davis Lock was replaced by a 1350 by 115 foot lock capable of handling Class 11 ships. The Sabin, MacArthur, and Poe Locks remained unchanged structurally. Non-structural alternatives were also implemented on the new Davis Locks.

(2) Performance Improvement

At the Welland Canal, non-structural improvements implemented to maximum utility extended capacity to 87,400,000 tons; this condition was reached in 1996. This tonnage, the maximum amount of cargo that would be processed through the Welland Canal without structural modifications, was held constant through 2050. Cargo flows using the Soo or St. Lawrence Locks which also use the Welland Canal were constrained to 1996 levels.

Using the cargo projections constrained by a capacity condition at the the Welland Canal, capacity through the existing St. Lawrence River Locks was reached in 2040. By implementing the non-structural alternatives to maximum utility, capacity through the St. Lawrence River Locks was extended beyond 2050.

Using the constrained cargo forecasts, the existing Soo Locks reached capacity in 2008 at a tonnage of 173,483,000 tons. By implementing non-structural alternatives to maximum utility, capacity at the Soo Locks was postponed to 2020 with a cargo volume of 191,944,000 tons. By constructing a new Davis Lock capable of handling Class 11 ships, the Soo Locks can pass the 2050 constrained cargo flows. The tonnage passed through the Soo in 2050 is 248,051,000 tons.

The 2050 cargo tonnage is about 9 percent less than the unconstrained 2050 cargo projection. The

cargoes that decreased significantly due to the constraint at the Welland Canal were grain and other bulk. Using the constrained cargo flows, the Soo Locks were not at capacity in 2050; average lock utilization was about 65 percent.

(3) Benefit-Cost Analysis

Table IV-10 summarizes the benefit-cost analysis. For the upper locks, rate savings are the largest benefit category, accounting for 81 percent of the benefits. Iron ore accounts for 56 percent of the rate savings; the average rate savings is $4.84 per ton. Grain accounts for 16 percent of the rate savings, with an average savings of $10.68 per ton. Other bulk accounts for 15 percent of the rate savings, with an average savings of $15.17 per ton. Delay savings are 12 percent of the benefits, and vessel utilization savings are 7 percent. Most of the vessel utilization savings are due to the use of larger ships for iron ore.

For the lower locks, rate savings account for 84 percent of the benefits. General cargo accounts for 45 percent of the rate savings (average savings of about $21 per ton) and grain accounts for 26 percent (average savings of $1.56 per ton in 2018). Delay savings are 16 percent of the benefits.

Regardless of the cost sharing assumption used, the benefit-cost ratio for the upper system and for the lower system is always greater than 10. The benefit-cost ratio for the entire scenario varies between 11 and 31.

TABLE IV-10
1350 X 115 Soo Lock and
Constrained Cargo Flows

| Lock System | Improvement | Average Annual U.S. Benefits ($ Million) Rate Savings | Delay Ben. | Vessel Util. Savings | Total |
|---|---|---|---|---|---|
| Upper | N/S to Max Utility | 13.47 | 1.60 | - | 15.07 |
| | 1350 X 115 Locks | 5.85 | 1.13 | 1.71 | 8.69 |
| | | 19.32 | 2.73 | 1.71 | 23.76 |
| Lower | N/S to Max Utility | 80.18 | 15.18 | - | 95.36 |

| Lock System | Cost Plan | Average Annual ($ Million) U.S. Benefit | U.S. Cost | Benefit-Cost Ratio |
|---|---|---|---|---|
| Upper | A | 23.76 | 2.00 | 11.9 |
| | B | 23.76 | 2.00 | 11.9 |
| | C | 23.76 | 2.00 | 11.9 |
| | D | 23.76 | 2.00 | 23.8 |
| Lower | A | 95.36 | 8.93 | 10.7 |
| | B | 95.36 | 4.47 | 21.3 |
| | C | 95.36 | 1.79 | 53.3 |
| | D | 95.36 | 4.47 | 21.3 |
| Total | A | 119.12 | 10.93 | 10.9 |
| | B | 119.12 | 6.47 | 18.4 |
| | C | 119.12 | 3.79 | 31.4 |
| | D | 119.12 | 5.47 | 21.8 |

# V. SUMMARY OF PHASE II

## V. SUMMARY OF PHASE II

The direct benefits of lock system improvements are rate savings resulting from continued use of the system instead of cargo being forced to use a more expensive route and mode, reduced delay at congested locks, and improved vessel productivity resulting from more cargo per locking operation.

Phase II evaluated other impacts of lock system improvements. These include:

- Energy savings which occur because lake transportation, which is relatively fuel-efficient, can continue to be used
- Induced industrial production potentially resulting from reduced lake freight rates
- Regional economic impacts, including port employment and income which are directly related to Great Lakes commerce
- Environmental and social impacts which might result from increased traffic or lock construction
- Intermodal impacts, which are measured in terms of net revenue gains or losses which would be incurred by the freight modes serving the Great Lakes region.

The evaluation of these potential impacts is summarized below.

### 1. ENERGY SAVINGS

The potential energy savings resulting from structural improvements to the upper and lower lock systems are summarized in Tables V-1 and V-2. respectively.

In general, improvements to the lower lock system produce smaller energy savings than improvements to the upper lock system because higher tonnages use the upper lock system. Structural improvements involving larger locks in general produce higher energy savings than those involving deepening of channels. Most of the energy savings resulting from upper locks improvements are attributable to iron ore, while at the lower locks energy savings are primarily attributable to general cargo.

TABLE V-1
Potential Energy Savings
(Upper Locks)

(Trillion Btus per Year)

| | 2010 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|
| 1350 X 115 Foot Locks | 1.9 | 6.7 | 11.9 | 17.6 | 23.1 |
| 1460 X 145 Foot Locks | 1.9 | 6.7 | 11.9 | 17.6 | 23.1 |
| 23 Foot System Draft | 1.9 | 6.7 | 9.8 | 9.8 | 9.8 |
| 32 Foot System Draft | 1.9 | 6.7 | 11.9 | 19.2 | 19.2 |

Note: All energy savings reflect implementation of non-structural improvements to maximum utility before structural improvements are implemented.

TABLE V-2
Potential Energy Savings
(Lower Locks)

(Trillion Btus per Year)

| | 1990 | 2000 | 2010 | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|
| 1350 X 115 Foot Locks | (1.3) | (1.8) | 1.2 | 2.0 | 4.4 | 6.6 | 8.1 |
| 1460 X 145 Foot Locks | (1.3) | (1.8) | 1.2 | 2.0 | 5.1 | 7.2 | 10.1 |
| 28 Foot System Draft | (1.3) | (1.8) | 1.3 | 1.8 | 3.2 | 3.8 | 3.8 |
| 32 Foot System Draft | (1.3) | (1.8) | 1.3 | 2.4 | 4.9 | 6.5 | 7.7 |

Note: All energy savings reflect implementation of non-structural improvements to maximum utility before structural improvements are implemented.

In 1977, U.S. freight transportation accounted for about 6.66 quadrillion Btus. The potential energy savings for 2030 identified above are 0.1 percent of the total; while these potential fuel savings are important, they represent a very small percentage of total fuel consumed for freight transportation.

## 2. INDUCED INDUSTRIAL PRODUCTION

Structural improvements could reduce lake freight rates because larger ships could be used (if larger locks were built) or ships could be loaded with more cargo (if system draft were deepened). Freight rate reductions of up to 30 percent could be achieved by the structural improvements analyzed in this report.

It is doubtful, however, that these freight rate reductions by themselves could induce higher industrial production in Great Lakes states. The potential impacts on the grain, coal and steel industries are discussed below.

### (1) The Grain Industry

The Great Lakes/St. Lawrence Seaway handles less than 15 percent of total U.S. grain exports. Fluctuations in grain transportation costs are normal and do not appear to affect export levels. Several economic factors influence grain production levels much more than transportation prices. A 20 percent reduction in freight rates would reduce the delivered price of grain by only 2 to 3 percent. Demand for wheat and corn is relatively insensitive to this level of price change, and it is highly doubtful that such a reduction in total prices would open new markets or increase existing demand.

### (2) The Coal Industry

Virtually all of the coal moving on the Great Lakes is bituminous coal. Most of the coal is mined in the U.S., more than 50 percent moves to domestic destinations, and most of the remainder is exported to Canada. The primary markets for this coal are electric utilities.

A 20 percent reduction in Great Lakes freight rates would cause only a 1 percent reduction in the delivered price of Appalachian coal, and a 4 percent reduction in the delivered price of western coal. This reduction is less than the average increase in the mine price of coal in the last few years. Since the price of electricity is heavily influenced by the

cost of generating equipment, the potential price reduction passed on to the consumer would be minimal, and would probably not be a factor in the demand for electricity.

(3) The Steel Industry

U.S. steel production is concentrated in the Great Lakes region, where the lakes are essential for iron ore transportation. Water transportation accounts for about 13 percent of the delivered price of iron ore, and the cost of iron ore is about 13 percent of the cost of finished steel. Consequently, a 30 percent decrease in iron ore transportation cost will produce only a 0.5 percent reduction in the cost of steel. This price reduction is not significant and would not influence the demand for steel.

## 3. REGIONAL ECONOMIC IMPACTS

Port activity generates tangible business activity for firms which participate in the transfer of cargo between ship and port, and which provide support services for ships while in port. In this study, port economic impact is measured in terms of income and employment. These two parameters are related by the wages of the sectors participating in port activity.

Table V-3 summarizes regional economic impacts resulting from 1350 by 115 foot locks. This lock improvement program will protect almost 4400 port employment positions in 1985, which would be lost if additional traffic were not able to use the Great Lakes system. The employment impact increases to 7300 jobs in the year 2010 and 23,000 positions by 2050. Regional economic impacts produced by even larger locks or deeper channels will be similar to those shown in the table.

Direct income related to port activity protected by the improvement program amounts to $97 million in 1985, increasing to $164 million in 2010 and $547 million in 2050. Part of this income would be respent within the local economy. For this analysis it was assumed that for every one dollar of income earned in the port community, an additional 40 cents is generated as a result of purchases of locally-produced goods and services.* This results in an income multiplier of 1.4.

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* Estimated by the Regional Income Multiplier System of the Bureau of Economic Analysis, U.S. Department of Commerce.

TABLE V-3
Summary of Regional Economic Impact
(1350 X 115 Foot Locks)

| | 1985 | 1990 | 2000 | 2010 | 2030 | 2050 |
|---|---|---|---|---|---|---|
| Employment (number of jobs) | | | | | | |
| Bulk cargo | 163 | 255 | 363 | 1,393 | 5,679 | 10,268 |
| General cargo | 4,228 | 2,079 | 2,911 | 5,933 | 10,660 | 13,213 |
| | 4,391 | 2,334 | 3,274 | 7,326 | 16,339 | 23,481 |
| Direct Income ($ million) | | | | | | |
| Bulk cargo | 4 | 6 | 9 | 34 | 141 | 256 |
| General cargo | 93 | 45 | 64 | 130 | 235 | 291 |
| | 97 | 51 | 73 | 164 | 376 | 547 |
| Total Income Including Respending ($ million) | 136 | 71 | 102 | 230 | 526 | 766 |

Note: This table identifies potential losses unless a capacity condition is corrected.

Income including respending is also shown in Table V-3. Total income is expected to be $136 million in 1985, increasing to $230 million in 2010 and $766 million in 2050.

## 4. ENVIRONMENTAL AND SOCIAL IMPACTS

Potential environmental and social impacts resulting from lock system improvements could be caused by dredging and lock construction, increased vessel traffic and the movement of larger vessels through these waterways. Areas which could be affected are discussed below.

### (1) Biological Impacts

System improvements will create some physical alteration of sediment in nearshore zones and connecting channels. However, biologic communities and aquatic vegetation will probably adjust to this disturbance in a relatively short period of time.

### (2) Impacts on the Physical Environment

Air, water and noise pollution associated with increased vessel traffic is expected to be minimal. There is concern, however, about the increased potential for accidental spills of fuel and petroleum cargoes due to founderings and collisions.

### (3) Impacts on the Quality of Life

It is not expected that lock construction, channel deepening or increased vessel activity will cause any substantial impact on the recreational uses of the lakes or on aesthetic values.

## 5. INTERMODAL IMPACTS

Intermodal impacts are measured in terms of the net increase or decrease of line-haul freight revenues accruing to the major segments of the U.S. freight carrier industry: railroads, motor carriers, barge operators and the U.S. flag Great Lakes and foreign trade fleets. These potential impacts were estimated by comparing modal revenue shifts with total annual revenues of each mode.

Table V-4 summarizes the intermodal impacts resulting from non-structural improvements for maximum utility, followed by 1350 by 115 foot locks. These impacts are summarized below.

- Lake carriers: The with-project case allows lake carriers to receive $10.3 million in revenue in 1985 that would have been lost if the system

TABLE V-4
Summary of Intermodal Impacts
($ million)

| | 1985 | 1990 | 2000 | 2010 | 2030 | 2050 |
|---|---|---|---|---|---|---|
| **Lake Carrier** | | | | | | |
| Total Revenue | 573 | 650 | 759 | 874 | 1,141 | 1,150 |
| Net Change | 10.33 | 17.1 | 30.8 | 81 | 311 | 553 |
| Percent Change | 1.8% | 2.6% | 4.1% | 9.3% | 27.3% | 36.1% |
| **Railroads** | | | | | | |
| Total Revenue | 13,369 | 15,063 | 19,433 | 25,071 | 41,728 | 69,452 |
| Net Change | (79) | (99) | (140) | (246) | (668) | (1,030) |
| Percent Change | * | * | * | * | (1.6%) | (1.5%) |
| **Motor Carriers** | | | | | | |
| Total Revenues | 15,568 | 17,188 | 20,952 | 25,540 | 37,951 | 56,394 |
| Net Change | 0.7 | 1.0 | 1.5 | 2.7 | 9.8 | 17.0 |
| Percent Change | * | * | * | * | * | * |
| **Barge & Towing Industry** | | | | | | |
| Total Revenues | 2,150 | 2,397 | 2,980 | 3,704 | 5,729 | 8,845 |
| Net Change | (25) | (34) | (50) | (59) | (101) | (113) |
| Percent Change | (1.2%) | (1.4%) | (1.7%) | (1.6%) | (1.8%) | (1.3%) |
| **U.S. Flag Liner Industry** | | | | | | |
| Total Revenues | 5,488 | 7,004 | 11,409 | 13,907 | 20,665 | 30,708 |
| Net Change | (20) | (18) | (14) | (15) | (52) | (64) |
| Percent Change | * | * | * | * | * | * |

* Less than 1 percent.

Note: Reflects non-structural improvements to maximum utility, followed by 1350 x 115 foot locks.

reached capacity. This revenue increases to $30.8 million in 2000 and $553 million in 2050. This represents 1.4 percent of this industry's revenue in 1985, increasing to 4.1 percent by 2000 and 36 percent by 2050.

- Railroads: The with-project case means a loss of the opportunity to collect $79 million in revenues in 1985, increasing to $140 million by the year 2000 and more than $1 billion in 2050. This is less than 2 percent of expected revenues in any of these years, however.

- Barge and towing industry: The with-project case means the loss of the opportunity to collect $25 million in revenue in 1985, increasing to $50 million in 2000 and $113 million in 2050. Similarly, this is less than 2 percent of total revenues in any of these years, however.

- Motor carriers: The with-project case means a change of less than 1 percent in any year until 2050.

- U.S. flag liner industry: The impact on the liner industry is negligible.

A positive impact means that the with-project case benefits the industry by allowing it to be able to handle traffic that would otherwise be forced off the system. The modes affected positively are the lake carriers and motor carriers. A negative impact means that lock improvements cause a modal industry to lose the opportunity to move traffic that would have been forced off the system in the absence of improvements. The modes affected negatively are railroads, the barge and towing industry and the U.S. flag liner industry. Except for the lake carriers, modal impacts even by the year 2050 can expect to remain at less than 2 percent of gross revenues.

The volume and commodity mix of the tonnage able to use the system after other types of structural improvements (larger locks and deeper channels) will be similar to that associated with 1350 by 115 foot locks. The intermodal impacts are expected to be similar as well.

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